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NEW EQUATION ON THE STUDY OF SLOW COAGULATION OF As_2S_3 SOL

By ABANI K. BHATTACHARYA, *Professor of Chemistry, Agra College, Agra.*

When a sol coagulates by the addition of an electrolyte, the agglomeration of the primary and the secondary particles takes place at a certain rate, designated as C. V. of the sol. The C. V. of the same sol when different electrolytes or the same electrolyte of different concentrations are added to the sol, are different. The same stage of coalescence during coagulation may be indicated by the same value of viscosity or the same time of efflux of a given volume of the coagulating mixture through a given capillary, or the same value of turbidity, or the same amount of absorption of light in a particular region or by others. This may also be indicated by the complete separation of the coagulated particles from the surface of the coagulating mixture. This paper deals only with the C. V. obtained by the method of visible surface separation of the coagulating particles.

According to Smoluchowski the total number of particles n, at any time t in a sol undergoing slow coagulation is given by the relation

$$\frac{n}{n_0} = \frac{1}{1+E\,\frac{t}{\theta}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where n is the number of primary particles, E is the factor for slow coagulation and is a constant. It is known that the time

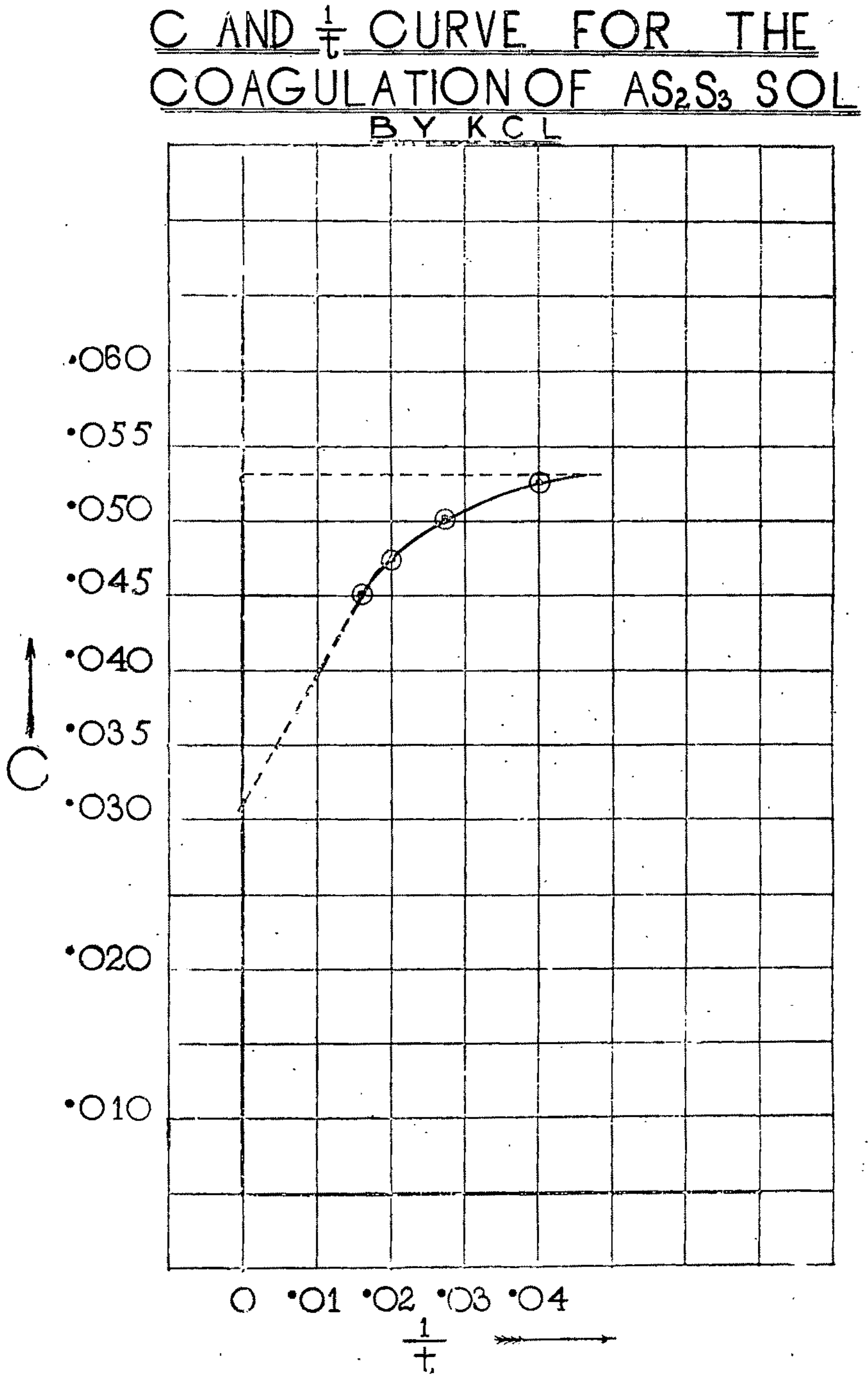


FIG. 1. Relation between C and $\frac{1}{t}$

of coagulation t of a sol by the same electrolyte of different concentrations, or the time t when a certain stage of agglomeration of particles (the same value of n) is reached, decreases as the concentration C of the electrolyte is increased. In other words $C \propto \frac{1}{t}$. From the Smoluchowski's equation given above, we find that E also varies inversely as t. Hence E should vary directly as C. No direct relation between C and E has, however, been established so far. In this paper an attempt is made to determine the relation between C and E, and hence between C and t, in the case of the coagulation of As_2S_3 Sol by different electrolytes by the method of visible separation of surface layer.

EXPERIMENTAL

Arsenious sulphide was prepared by the well known method of bubbling hydrogen sulphide through distilled water and adding a saturated solution of arsenious acid in regular drops, when colloidal arsenious sulphide is formed. Excess of hydrogen sulphide was removed by a stream of hydrogen bubbled through the sol. The concentration of the colloidal solution was estimated by precipitating arsenious sulphide with hydrochloric acid, filtering through a sintered glass crucible and then drying at 105° C to constant weight.

The standard solutions of the electrolytes were prepared in some cases by weighing the quantities required for the strength desired, and by gravimetric or volumetric estimation in such cases where direct weighing was not possible. The electrolytes used were chlorides of potassium, sodium, lithium, barium, calcium, magnesium, aluminium and chromium.

Results obtained are given in the following tables.—

TABLE I

Conc. of Sol	Electrolyte	Electrolyte conc.	Time of coagln. t	$\frac{1}{t}$	a	$\frac{1}{c-a} \times 10^{-2}$	m	n
0·00525M	KCl	0·0525M	25 mts.	0·040		0·49		
		0·0500M	37 mts.	0·027	·032M	0·55	0·021M	0·025
		0·0475M	50 mts.	0·020		0·65		
		0·0450M	60 mts.	0·016		0·78		
0·00235M	NaCl	0·070M	15 mts.	0·066		0·28		
		0·065M	20 mts.	0·050	·0345M	0·32	0365M	0·0246
		0·065M	28 mts.	0·035		0·39		
		0·055M	34 mts.	0·029		0·47		
0·00407M	LiCl	0·072M	12 mts.	0·083		0 66		
		0·070M	18 mts.	0·055	·0575M	0.80	·0150M	·0294
		0·067M	23 mts.	0·043		1.00		
		0·065M	31 mts.	0·033		1.30		

TABLE II

Conc. of Sol	Electrolyte	Conc. of electrolyte	Time of coagln. t	$\frac{1}{t}$	a	$\frac{1}{c-a} \times 10^{-2}$	m	n
0·0023M	$BaCl_2$	0·00060M	10 mts.	0·100	0·00029M	0·327	0·00032M	0·000246
		0·00055M	26 mts.	0·038		0·380		
		0·00050M	34 mts.	0·029		0·476		
		0·00045M	45 mts.	0·022		0·620		
0·00323M	$MgCl_2$	0·00037M	12 mts.	0·088	0·00025M	0·80	$\frac{m}{n}$ =·1584	...
		0·00034M	19 mts.	0·052		1·36		
		0·00031M	30 mts.	0·033		1·61		
		0·00028M	52 mts.	0·019		3·22		
0·0044M	$CaCl_2$	0·00080M	17 mts.	0·058	0·00025M	0·181	0·00057M	0·000414
		0·00075M	23 mts.	0·043		0·200		
		0·00070M	28 mts.	0·035		0·220		
		0·00065M	32 mts.	0·031		0·250		

TABLE III

Conc. of Sol	Electrolyte	Conc. of electrolyte	Time of coagln.	$\frac{1}{t}$	a	$\frac{1}{c-a} \times 10^{-2}$	m	n
0·00313M	$AlCl_3$	0·000051M	8 mts.	0·120	0·0000275M	0·43	$\frac{m}{n}$=0·2126	...
		0·000045M	14 mts	0·074		0·57		
		0·000039M	18 mts.	0·055		0·87		
		0·000035M	28 mts.	0·036		1·33		
0·00325M	$CrCl_3$	0·000060M	10 mts.	0·100	0·0000325M	0·37	0·0000275M	0·0000648
		0·000055M	15 mts.	0·060		0·44		
		0·000050M	23 mts.	0·043		0·57		
		0·000045M	32 mts.	0·031		0·80		

DISCUSSION

The curves obtained on plotting the values of C against $1/t$ are of the same type in almost all cases. In a very few cases, however, straight line is obtained. A typical case is shown in fig. 1. It is found that the relation between C and $\frac{1}{t}$ is best satisfied by an equation of the form

$$c=a+\frac{m\frac{1}{t}}{n+\frac{1}{t}} \qquad \text{......................(2)}$$

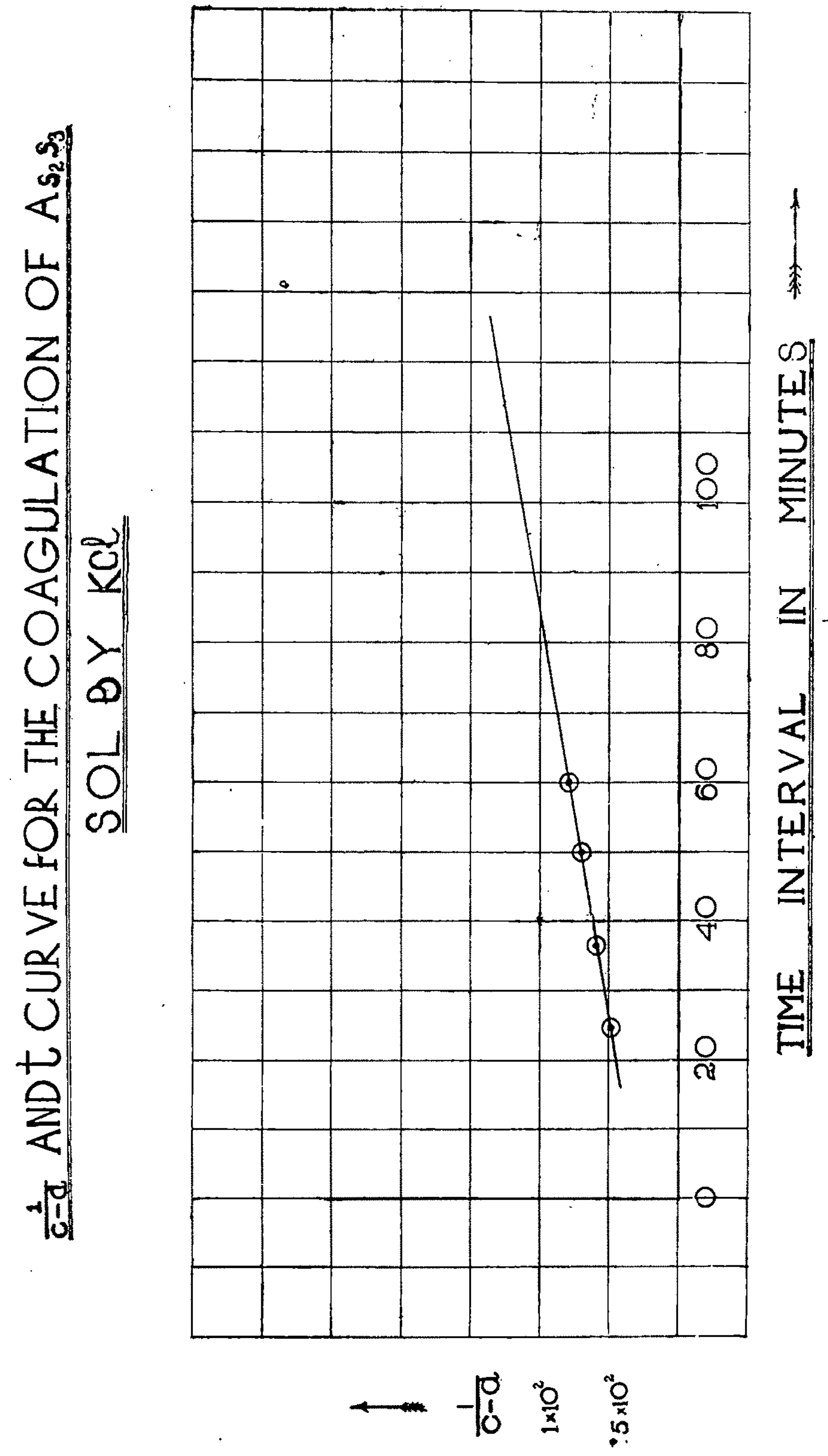


FIG. 2 Relation between $\frac{1}{c-a}$ and t.

where a, m, and n are constants, and C and t have their usual meanings.

For $\frac{1}{t}=0$, $C=$ a. This means that a is the concentration of the electrolyte which will bring about the coagulation of the sol by the same electrolyte in infinite time. The values of a were read in each by the extrapolation of $C-\frac{1}{t}$ curves and are given in column 6 of the tables. The equation (2) can be written as

$$\frac{1}{c-a}=\frac{n}{m}t+\frac{1}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

This shows that the plot of $\frac{1}{c-a}$ against t should be a straight line. This has been found to be so in all cases. The values of m and n have been determined and are given in columns 8 and 9 of the tables.

An attempt has been made to correlate the value of E in terms of C. The following three possibilities have been tried:—

(i) $E=k\ (c-a)$
(ii) $E=k\ (c-a)^n$
(iii) $E=\frac{k\ (c-a)}{k_1-k_2\ (c-a)}$

For the same value of $\frac{n}{n_o}$ Et. is constant.

Hence, the following three equations are obtained

(i) $k\ (c-a)t=k_1$
(ii) $k\ (c-a)^n t=k_2$
(iii) $\frac{k\ (c-a)}{k_1-k_2\ (c-a)}t=k_3$

where $K_1 K_2$ and K_3 are constants.

Equation (i) gives

$$C=a+\frac{k_1}{k}\left(\frac{1}{t}\right)$$ which represents a straight line.

Equation (ii) gives

$$C=a+\frac{k_2}{k}\left(\frac{1}{t}\right)^{\frac{1}{n}}$$ which represents a curve with characterisic bend.

Equation (iii) gives

$$C=\frac{k^{1}}{k^{11}}\cdot\ \frac{1}{t}\ \frac{k^{111}}{k^{11}}+\frac{1}{t}\ or\ C=\frac{m\quad\frac{1}{t}}{n+\frac{1}{t}}$$

which is the general equation proposed.

Equation (iii), therefore, gives the same form as the proposed equation (2). Hence the relation between C and t is given by the general equation iii, assuming that Smoluchowski's relation is true. This equation has been tried with a number of lyophobic sols and has been found to be satisfactory. Further work is in progress.

ACKNOWLEDGMENTS

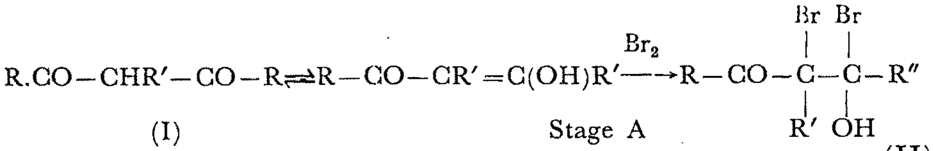
Thanks are due to Dr. Rama Kumar, Lecturer in Chemistry, B. R. College, Agra, for his collaboration in the investigations and development of the new equation, and to Mr. R. K. Srivastava for testing the equation with the experimental data on coagulation.

A CRITICAL STUDY OF K. H. MEYER'S METHOD APPLIED TO ESTIMATION OF ENOL IN AN ALDEHYDE-ENOL EQUILIBRIUM MIXTURE

By M. M. Bokadia, *Assistant Professor of Chemistry, B. R. College, Agra.*

It has been observed by Bokadia and Deshpande (2, 3, 4) that the various methods which are used to estimate enol in a keto-enol equilibrium mixture, give divergent values when the equilibrium mixture is that of an aldehyde and the corresponding enol as in the case of ∝-acyl aldehydes or 2-formyl ketones (R-CO-CHR'—CHO⇌R-CO-CR'=CHOH). In this paper the method of K. H. Meyer—the most widely used method—is critically examined in regard to the assumptions on which it is based and the modifications that have to be made in it to make it applicable in the case of unsaturated 2-formyl ketones and bromo-2-formyl ketones.

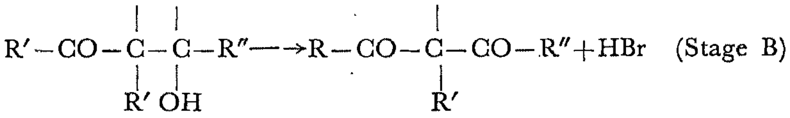
The procedure in K. H. Meyer's process (5, 6, 7) consists of:—(1) addition of alcoholic bromine in excess to alcoholic solution of the equilibrium mixture at -15°C and removal of the excess of bromine by adding alcoholic β-naphthol. This must be completed within 15 seconds. It is assumed that the reagent adds instantaneously only at the ethylenic bond of the enol and the excess of it combines with β-naphthol to form ∝-bromo β-naphthol



$$\mathrm{R.CO{-}CHR'{-}CO{-}R \rightleftharpoons R{-}CO{-}CR'{=}C(OH)R' \xrightarrow{Br_2} R{-}CO{-}\underset{\displaystyle R'}{\overset{\displaystyle Br}{C}}{-}\underset{\displaystyle OH}{\overset{\displaystyle Br}{C}}{-}R''}$$

(I) Stage A (II)

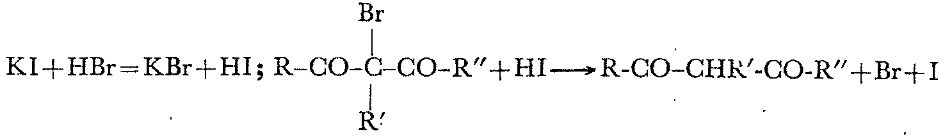
The dibromo addition product (II) then loses hydrobromic acid to form the bromoketone (III).



$$\mathrm{R'{-}CO{-}\underset{\displaystyle R'}{\overset{\displaystyle Br}{C}}{-}\underset{\displaystyle OH}{\overset{\displaystyle Br}{C}}{-}R'' \longrightarrow R{-}CO{-}\underset{\displaystyle R'}{\overset{\displaystyle Br}{C}}{-}CO{-}R''+HBr} \quad \text{(Stage B)}$$

(II) (III)

(2) addition of aqueous potassium iodide in excess to the acid medium. This liberates iodine (2 atoms) which is estimated volumetrically.



$$KI+HBr=KBr+HI;\ R\text{-}CO\text{-}\underset{R'}{\overset{Br}{C}}\text{-}CO\text{-}R''+HI\longrightarrow R\text{-}CO\text{-}CHR'\text{-}CO\text{-}R''+Br+I$$

(III) (I)

$HI+Br=HBr+I$ (Stage C)

The reduction of the bromoketone (III) to the original ketone (I) is known as 'inverse substitution.'

The assumptions on which the process is based are:—

(a) the addition of bromine at the ethylenic double bond of the enol is instantaneous at stage A.

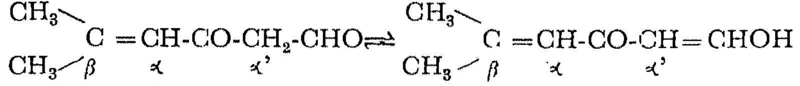
(b) the inverse substitution is quantitative at stage C.

(c) the α- bromo β-naphthol formed at stage A does not likewise undergo inverse substitution as the bromoketone (III).

The assumption (a) seems to be valid generally. The compounds (Nos. 1, 5, 8, 9, and 12) described in the Table I are pure crystalline solids, and as they are enols they must be completely enols. Since, by the application of K. H. Meyer's process they liberate two atoms of iodine per molecule, the assumption (a) as well as (b) must be valid. The validity of the assumption (b) has also been independently established by the author by synthesising bromoketones of type (III) and treating them in acid medium with excess of potassium iodide when two atoms of iodine per molecule of the bromoketone are liberated. Assumption (c) seems also to be valid generally because in acid medium in presence of excess of potassium iodide α-bromo β-napthol does not liberate iodine by reversion to β-napthol unless the medium is saturated with hydrobromic acid.

Although the validity of the assumptions (a) and (b) has been tested and is generally found to be true, it is obvious that these cannot be true under all circumstances but must be influenced by a constitutional factor. For instance as regards instantaneous addition of bromine at the ethylenic bond [assumption (a)] Sudborough and Thomas (8) have shown that the $\alpha\beta$ unsaturated acids absorb bromine only slowly as compared to the $\beta\alpha$ unsaturated acids. Again according to Baner (1) dimethyl fumaric and dibromo crotonic acids having a reduplication of a group on each of the doubly bound carbons do not add bromine. It follows, therefore, that even when there is no reduplication of a group, such as bromine, but its attachment to only one of the doubly bound carbons as in the case of a bromo enol $R.\ CO\text{-}C(OH){=}CBr\text{-}R^1$ the constitutional factor must operate and the addition of bromine at the double bond must be protracted though not altogether extinct. This 'protraction' inevitably will result in incomplete addition of the reagent in the stipulated period of fifteen seconds and consequently the iodine that will appear at the end of stage C will be less than what should correspond to the true enol content of the equilibrium mixture. This seems to be the explanation of the low 'enol' values of α-bromo ethyl aceto-acetate $CH_3\text{-}CO\text{-}CHBr\text{-}CO_2Et \rightleftharpoons CH_3\text{-}C(OH){=}CBr\text{-}CO_2\,Et$ as compared to the enol content of ethylaceto-acetate although in reality the inductive effect of bromine attached to α-carbon should facilitate expulsion of hydrogen attached to the same carbon as proton and should consequently lead to higher enol content. That the value of enol content of bromo enols determined by K. H. Meyer's method is defective is proved by two independent pieces of evidence. Firstly, the author has prepared certain crystalline bromo enols which are perfectly pure and homogeneous. They must therefore be hundred per cent. enol. But K. H. Meyer's process applied to the measurement of their enol content gave values as low as sixty per cent or even. less. Secondly, in the case fo liquid like α-bromo ethylaceto-acetate the enol value determined by other methods, was, as expected found to be greater than that of ethylaceto-acetate although K. H. Meyer's process as mentioned above leads to the contrary results.

The validity of assumption (b). is also influenced by constitutional factor. In the case of 2-formyl derivative of an $\alpha\beta$- unsaturated ketone such as 2-formyl mesityl oxide.



$$\underset{CH_3\diagup\beta}{\overset{CH_3\diagdown}{}}C=\underset{\alpha}{CH}\text{-}CO\text{-}\underset{\alpha'}{CH_2}\text{-}CHO \rightleftharpoons \underset{CH_3\diagup\beta}{\overset{CH_3\diagdown}{}}C=\underset{\alpha}{CH}\text{-}CO\text{-}\underset{\alpha'}{CH}{=}CHOH$$

The action of bromine will not only lead to α' bromination depending upon the amount of enol content, but also to a certain amount of $\alpha\beta$-bromine addition within the stipulated short period in K. H. Meyer's process. Further at the stage (c) of inverse substitution not only the α' bromine but α-bromine* also will give rise to two atoms of iodine. To find the inverse substitution due to α-bromine only—which is the measure of the enol content in the equilibrium mixture—the simple and rational method would be to deduct the amount of iodine liberated due to inverse substitution of α-bromine from the total amount of iodine liberated (due to α as well as α'-bromine.) It is obviously necessary that the effect of inverse substitution of α bromine must be measured within the stipulated short period. In other words a blank K. H. Meyer's estimation should be done upon the compound $R\text{-}CH{=}CH\text{-}CO\text{-}CH_2R'$ and the iodine liberated should be deducted from that obtained by doing the process on the corresponding 2-formyl derivative $R.\ CH{=}CH\text{-}CO\text{-}CH_2\text{-}CHO \rightleftharpoons R\text{-}CH{=}CH\text{-}CO\text{-}CH{=}CHOH$.

The influence of the constitutional factor on the assumptions (a) and (b) in K. H. Meyer's process and the need for taking into account the limitations of the process, has been exemplified in this paper by showing results obtained with compounds like α-bromo α-formyl acetone, 2-bromo 2-formyl aceto phenone, 2-formyl mesityl oxide, and 2-formyl carvone. The validity and perfect correctness of the assumptions have also been exemplified in cases of such pure enols like hydroxymethylene methylethyl ketone, hydroxy methylene diethyl ketone, hydroxymethylene cyclopentanone and hydroxymethylene camphor.

TABLE I

Enol content of 2-formyl ketones by K. H. Meyer's method.
(N. B.—The references are regarding the preparation of the compounds).

Name of compound	Wt. used (gms)	Strength of $Na_2S_2O_3$	Titre (cc.)	Enol %
1. Hydroxymethylene methyl ethyl ketone.	0.2348 0.1521	0.105 N 0.105 N	43.0 27.9	96.16 96.3
2. Hydroxymethylene methyl n-propyl-ketone. (Claisen and Steindorff Ber. 1888, **21**: 1144).	0.2428 0.1575	0.106 N 0.106 N	24.8 16.1	61.7 61.8
3. Hydroxymethylene methyl n-butyl ketone. (Synthesised by the author).	0.1234 0.2124	0.1041 N 0.1041 N	12.6 21.7	68.03 68.07

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*It has been shown by the author (3) that "inverse substitution" works quantitatively even in the case of a simple α-bromoketone like bromoa-cetone. But with an αβ dibromoketone R-CHBr-CHBr-CO-R' the β bromine remains unaffected in the process.

4.	Hydroxymethylene methyl n-amyl ketone.	0.2632	0.0876 N	31.7	74.91
		0.2790	0.0876 N	33.6	74.9
5.	Hydroxymethylene Di-ethyl ketone.	0.1172	0.1004 N	20.7	101.0
		0.0885	0.1004 N	15.3	98.92
	(Claisen and Meyer Owitz ; Ber. 1889, **22:** 3275).				
6.	Hydroxymethylene di-n-propyl ketone.	0.4398	0.0991 N	43.5	69.59
		0.2520	0.0991 N	24.9	69.52
	(Agarwal, Gupta and Deshpande : J. Ind. Chem. Soc. 1951, **28:** 95).				
7.	Hydroxymethylene Valerone.	0.4462	0.1038 N	15.6	30.85
		0.3052	0.1038 N	10.6	30.8
	(Agarwal, Gupta, Deshapande. ibid.)				
8.	Hydroxymethylene desoxy benzoin.	0.2248	0.1312 N	13.8	90.21
		0.3484	0.1312 N	21.4	90.5
	(Wislicenus and Ruthing Ann. 1911, **379:** 238).				
9.	Hydroxymethylene cyclopentanone.	0.1172	0.1004 N	20.7	99.28
		0.1312	0.1004 N	23.1	98.98
	(Wallach & Steindorff : Ann. 1903, **329:** 114).				
10.	Hydroxymethylene cyclo-Hexanone.	0.5697	0.105 N	62.4	72.46
		0.2308	0.105 N	25.3	72.52
	(Wallach and Steindorff : Ibid.).				
11.	Hydroxymethylene Menthone.	0.3826	0.0994 N	31.3	74.0
		0.3317	0.0994 N	27.1	73.9
	(Bishop, Claisen & Sinclair ; Ann. 1894, **281:** 394).				
12.	Hydroxymethylene Camphor.	0.2972	0.1082 N	29.3	96.1
		0.3662 A	0.1082 N	36.1	96.0
	(Bishop, Claisen and Sinclair : Ann. **281:** 328).				
13.	Hydroxymethylene amyl butyrate.	0.2636	0.0987 N	13.3	46.35
		0.3244	0.0987 N	16.4	46.4
	(Synthesised by the author).				

Enol Content of 2-formyl unsaturated ketones by K. H. Meyer's Method—

As shown in the theoretical part a correction must be applied in these cases. To find this correction a weighed quantity of the parent unsaturated ketone was treated as in the K. H. Meyer's method and the iodine so liberated measures the correction for it.

	BLANK-READING		
Compound	Weight	Strength of $Na_2S_2O_3$	Titre
1. Carvone.	0.2499 g.	0.1038 N	1.4 cc.
,,	0.4022 g.	0.1038 N	1.6 cc.
2. Mesityl oxide.	0.2944 g.	0.1038 N	0.3 cc.
,,	0.4724 g.	0.1038 N	0.5 cc.

Enol content of 2-formyl bromo ketones and 2-formyl bromo ester by K. H. Meyer's Method.

While estimating enol in the halogen substituted compounds by K. H. Meyer's method a correction was applied for the oxi-

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N. B. From the correction values it is evident that the addition across the ethylenic double bond is very small in course of K. H. Meyer's bromine addition process.

TABLE II

Enol contents of 2 formyl unsaturated ketones as found by K. H. Meyer's Method.

	Compound	Weight (gms.)	Strength of $Na_2S_2O_3$	Total titre.	Titre for ethylenic double bond.	Titre for enol.	Enol %
1.	Hydroxymethylene Carvone.	0.2720	0.0876N	1.3 cc.	1.28 cc	30.02	83.87
		0.2153	0.0876N	24.2 cc.	0.99 cc	23.21	84.04
2.	Hydroxymethylene mesityl oxide.	0.4110	0.1038N	13.5	0.33	13.17	20.95
		0.5788	0.1038N	19.0	0.47	18.53	20.93

dation of potassium iodide by the compound itself. The correction was found by dissolving a known weight of the compound in 25 cc of absolute alcohol, adding to it an aqueous solution of potassium iodide and dilute sulphuric acid, warming the mixture gently and titrating the iodine liberated against standard thiosulphate solution.

BLANK-READING

Compound	Weight (gms)	Strength of Thiosulphate	Titre (cc)
Hydroxymethylene w-bromo-acetophenone.	0.1962	0.1041 N	16.6
	0.1590	0.1041 N	13.4
Hydroxymethylene bromo-acetone.	0.2968	0.2008 N	17.6
	0.4412	0.2008 N	26.1
Hydroxymethylene bromo-ethyl acetate.	0.1477	0.1021 N	14.8
	0.1864	0.1021 N	18.7

TABLE III

Enol contents of 2-formyl bromo ketones and 2-formyl bromo ester as found by K. H. Meyer's Method.

	Compound	Weight (gms)	Strength of $Na_2S_2O_3$	Total titre (cc.)	Correction for the oxidation due to bromine. (cc)	Titre due to enol. (cc.)	Enol%
1.	Hydroxymethylene w-bromo-acetophenone	0.1344	0.1041 N	19.0	11.25	7.75	68.13
		0.1615	0.1041 N	22.7	13.52	9.18	67.16
2.	Hydroxymethylene Bromo-acetone.	0.1444	0.09237 N	29.5	18.97	10.53	55.57
		0.1876	0.09237 N	38.3	24.65	13.65	55.45
3.	Hydroxymethylene bromo ethyl acetate.	0.1324	0.1021 N	23.7	13.3	10.4	78.2
		0.1732	0.1021 N	31.1	17.4	13.7	78.7

TABLE IV

Inverse substitution in bromo compounds under the conditions employed in K.H. Meyer's Method.

	Compound	Weight (gms.)	Strength of $Na_2S_2O_3$	Titre (cc)	Iodine liberated by 1 g. mol, of compound.	Mols. of iodine by 1 mol. of compound
1.	2-bromo acetone.	0.1896	0.1022 N	27.1	254.1	1.0
		0.2324	0.1022 N	33.2	254.1	1.0
2.	1-bromo methyl ethyl ketone	0.4250	0.0963 N	57.3	249.0	0.98
		0.5554	0.0963 N	74.7	248.3	0.97
3.	3-bromo methyl ethyl ketone.	1.3071	0.0963 N	174.0	245.9	0.96
		0.2994	0.0963 N	39.9	246.1	0.97
4.	w-bromo-acetophenone.	0.2246	0.1312 N	17.2	253.9	1.0
		0.2632	0.1312 N	20.1	253.2	0.99
5.	Bromo di-n-propyl ketone.	0.4512	0.0963 N	47.6	249.0	0.98
		0.2024	0.0963 N	21.2	247.2	0.97
6.	Bromo valerone.	0.1182	0.0963 N	10.1	230.9	0.91
		0.1992	0.0963 N	17.3	234.7	0.91
7.	Bromo cyclo Hexanone.	0.1816	0.092 N	21.2	241.4	0.95
		0.1358	0.092 N	15.8	240.1	0.94
8.	α-Bromo-propio-phenone.	0.1242	0.1052 N	10.2	233.7	0.92
		0.1862	0.1052 N	15.3	233.8	0.92
9.	Hydroxymethylene bromo-acetone.	0.2968	0.2008 N	17.6	249.5	0.98
		0.4412	0.2008 N	26.1	248.9	0.98
10.	Hydroxymethylene w-bromo acetophenone.	0.1004	0.1041 N	8.4	251.1	0.98
		0.1732	0.1041 N	14.5	251.3	0.98
11.	α-bromo ethyl aceto-acetate.	0.7655	0.1041 N	70.0	252.5	0.99
		0.2132	0.1041 N	19.5	252.7	0.99
12.	αα dibromo ethyl aceto acetate	0.8411	0.1312 N	87.5	499.2	1.9
		0.2130	0.1312 N	22.1	497.8	1.9
13.	Tetrabromo pharone.	0.4274	0.0995 N	35.6	482.1	1.9
		0.2616	0.0995 N	22.1	488.9	1.92
14.	Dibromo benzal acetone.	0.1242	0.0991 N	8.3	257.3	1.01
		0.2376	0.0991 N	16.0	259.3	1.02
15.	Dibromo dibenzal acetone.	0.4308	0.0991 N	22.3	256.7	1.0
16.	Tetra bromo dibenzal acetone.	0.2682	0.0995 N	18.8	490.7	1.9
		0.5456	0.0995 N	38.2	490.1	1.9

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CONDENSATION OF MALON-*o*-, *m*- AND *p*-TOLUIDIC ACIDS WITH VANILLIN, VERATRALDEHYDE AND PIPERONAL

By P. I. Ittyerah and Kantilal C. Pandya, *Chemistry Department, St. John's College, Agra.*

The condensation of malonic acid with protocatechuic aldehyde, vanillin, veratraldehyde and piperonal in the presence of traces of various organic bases like pyridine and piperidine has been reported by Pandya and Vahidy (3, 4, 5) and by Pandya and Sodhi (6, 7). The reaction of the same aldehydes with malonanilic acid has been studied and the results reported by Ittyerah and Pandya (2). The present paper deals with the condensation of malon-*o*-*m*- and *p*-toluidic acids with vanillin, veratraldehyde and piperonal.

All earlier experiments have shown that the presence of a hydroxyl group in the aldehyde molecule exerts a strong inhibitive effect on the activity of the aldehyde group. This is most noticeable when the hydroxy group is ortho to the aldehyde group. In the case of poly-hydroxy aldehydes this effect is stronger. Thus when protocatechuic aldehyde was condensed with malonanilic acid nothing but a dark resinous mass was obtained. This could not be further purified and any definite product isolated.

With replacement of the hydroxy groups one by one by methoxy groups, a steady progress in the yield of products was noted. Vanillin when condensed with malon-*o*-toluidic acid, gave 12 per cent. yield of 3-methoxy-4-hydroxybenzylidene-malon-*o*-toluidic acid and 42.4 per cent. yield of 3-methoxy-4-hydroxy-cinnam-*o*-toluidide. Veratraldehyde gave 41 per cent. yield of 3:4 -dimethoxy-benzylidene-malon-*o*-toluidic acid and 87.5 per cent. yield of 3:4-dimethoxy-cinnam-*o*-toluidide. When the hydroxy groups in protocatechuic aldehyde are replaced by a methylenedioxy group the yields are better than those given by veratraldehyde. Piperonal gave 49 per cent. yield of 3:4-methylenedioxy-benzylidene-malon-*o*-toluidic acid and 92.5 per cent. yield of 3:4-

methylenedioxy-cinnam-*o*-toluidide. These observations relating to the effect of substituent groups in these aldehydes is further supported by the results obtained in the condensation of these aldehydes with malon-*m*-toluidic acid and with malon-*p*-toluidic acid. Pandya and co-workers, to whose work reference has already been made in this paper, have made the same observation in the condensation of these aldehydes with malonic acid and with malonanilic acid.

It may also be mentioned that the reactivity of the methylene group in malon-*o*-, *m*- and *p*-toluidic acids is of the same order as that of the methylene group in malonic acid. The replacement of one of the carboxylic groups in malonic acid by a carboxy-*o*-, *m*- or *p*-toluidide group does not seem to interfere with the reactivity of the methylene group. A comparison of the results reported in this paper with the results reported by Pandya and co-workers (*loc. cit.*) in the case of malonic acid condensations will support this view.

The condensations have been carried out under various conditions. All the aldehydes gave two products in each case, (a) the corresponding benzylidene-malon-toluidic acid R. $CH=C(COOH)\text{-}CO—NH—C_6H_4$ Me) and (b) the corresponding cinnamtoluidide ($R.CH=CH—CO—NH—C_6H_4$ Me). The presence of a trace of an organic base like pyridine or piperidine catalysed the reactions. At the same time they promoted decarboxylation of the products. When either of them was used, the product was mainly the cinnamtoludide and when no condensing agent was used the product was mainly the benzylidene-malon-toluidic acid.

Of the aldehydes metioned, veratraldehyde and piperonal have been condensed with malon-*o*-toluidic acid by Ahluwalia, Haq and Ray (1). Though these authors do not mention the yields of the products they obtained, they have described the isolation of 3:4-dimethoxy-benzylidene-malon-*o*-toluidic acid, 3:4-dimethoxy-cinnam-*o*-toluidide, 3:4-methylenedioxy-benzylidene-malon-*o*-toluidic acid and 3:4-methylenedioxy-cinnam-*o*-toluidide. All the other products described in this paper are, as far as is known, prepared for the first time.

EXPERIMENTAL

Condensation of malon-o-toluidic acid with vanillin, veratraldehyde and piperonal

a. *With vanillin*

1. *Without any condensing agent.* 1.5 gm. vanillin and 2gm. of malon-*o*-toluidic acid were heated on water-bath for four hours. The product left was extracted with a saturated solution of sodium bicarbonate. The alkali extract was separated and the residue left was found to be unreacted vanillin. The alkali extract was acidified with concentrated hydrochloric acid. A sticky pale blue precipitate was obtained. This on keeping for sometime became brittle. After filtering and then recrystallising from alcohol it melted and decomposed at 183°C. This substance was analysed and found to be 3-methoxy-4-hydroxy-benzylidene-malon-*o*-toluidic acid. Yield was 0.3 gm. (9.17 per cent.) Found Nitrogen$=4.32\%$: $C_{18}H_{17}O_5N$ requires 4.28%.

In another experiment the same quantities of aldehyde malon-*o*-toluidic acid when heated at 100°C for eight hours yielded 0.4 gm. (12.2 per cent.) of 3-methoxy-4-hydroxy-benzylidene-malon-*o*-toluidic acid.

2. *With a trace of pyridine.* 1 gm. of malon-*o*-toluidic acid and 0.75 gm. of vanillin and 0.1cc of pyridine were mixed and heated at 100°C for four hours. The brown viscous mass left was extracted with a solution of sodium bicarbonate. The alkali extract was acidified with concentrated hydrochloric acid but no precipitate was obtained. The brown semi-solid residue left after extraction with alkali was dissolved in hot acetone and then diluted with water. An oily liquid separated out. This oily liquid when kept in ice for a few minutes solidified. This was filtered and the solid obtained was repeatedly recrystallised from acetone and alcohol. A white crystalline solid was obtained which softened at 160°C and melted at 163°C. This was analysed and found to be 3-me-

thoxy-4-hydroxy-cinnam-*o*-toludide. Yield 0.6 gm. (42.2 per cent.) Found Nitrogen=4.81% : $C_{17}H_{17}O_3N$ requires 4.94%.

b. *With veratraldehyde*

1. *With no condensing agent.* 1 gm. of malon-*o*-toludic acid and 0.8 gm. of veratraldehyde were heated at 100°C for four hours. On extracting the brown viscous mass in the usual manner described in previous experiments, 0.6 gm. of 3: 4-dimethoxy-benzylidene-malon-*o*-toluidic acid was obtained. It melted and decomposed at 217°C. Ahluwalia, Haq and Ray who have prepared this compound earlier by a different method, report 219°C as its melting point.

In another experiment when the same quantities of the aldehyde and the acid were heated for six hours at 80°, 0.7 gm. of 3:4-dimethoxy-benzylidene-malon-*o*-toluidic acid was obtained. Yield 41%.

2. *With a trace of piperidine.* When a trace of piperidine (0.1 cc) was added to the same quantities of aldehyde and acid as mentioned in the previous experiment and heated for four hours at 100°, and extracted, 1.3 gm. of a white crystalline compound was obtained. This after recrystallisation from dilute alcohol, melted at 159°. This decolorised alkaline potassium permaganate and bromine water, was soluble in acetone and alcohol. On analysis this was found to be 3:4-dimethoxycinnam-*o*-toluidide. Found Nitrogen=4.75%:$C_{18}H_{19}O_3N$ requires 4.71%. Yield 87.5 per cent.

c. *With Piperonal*

1. *With no condensing agent.* 0.7 gm. of piperonylidene-malon-*o*-toluidic acid was formed when 1 gm. of malon-*o*-toluidic acid and 0.75 gm. of piperonal were heated at 100° for four hours. It melted with decomposition at 213°. Yield 43.1 per cent. Ahluwalia, Haq and Ray have prepared the same compound and report the same melting point.

49.2 per cent. yield of piperonylidene-malon-*o*-toluidic acid was obtained in a similar experiment but with time of heating extended to six hours.

2. *With a trace of piperidine.* 1 gm. of malon-*o*-toluidic acid, 0.75 gm. of piperonal and 0.1 cc of peiperidine when mixed and heated on water-bath for two hours gave 1.3 g. of 3:4-methylenedioxycinnam-*o*-toluidide. This melted at 181°. Yield 92.5 per cent. Ahluwalia, Haq and Ray report the same melting point.

3. *With a trace of pyridine.* 85 per cent. yield of 3:4-methylenedioxy-cinnam-*o*-toludide and 12.5 per cent. yield of piperonylidene-malon-*o*-toluidic acid were obtained when 1gm. of malon-*o*-toluidic acid and 0.75 gm. of piperonal were heated in presence of 0.1 cc of pyridine for six hours on water-bath.

Condensation of malon-m-toluidic acid with vanillin, veraltraldehyde and piperonal

a. *With vanillin*

1. *Without any condensing agent.* 2 gm. of malon-*m*-toluidic acid and 1.5 gm. of vanillin were heated together on a water-bath for six hours. The mass left on extraction gave 0.5 gm. of an acid product and a brown viscous non-acidic mass. The non-acidic substance was identified to be unreacted vanillin. The acid product after recrystallisation from alcohol melted with decomposition at 196°. This on analysis was found to be 3-methoxy-4-hydroxy-benzylidene-malon-*m*-toluidic acid. Yield 15.2 per cent.

Found Nitrogen—4.54% : $C_{18}H_{17}O_5$ N requires 4.28%.

2. *With a trace of pyridine.* 2 gm. of malon-*m*-toluidic acid, 1.5 gm. of vanillin and 0. 2 cc of pyridine were mixed and heated on water-bath for four hours. The brown oily liquid left was found to be non-acidic and was extracted with a small quantity of hot acetone. The whole mass dissolved in acetone. As no crystals separated on cooling the acetone solution, it was diluted with water. An oily liquid separated out. This was cooled in ice for two days but did not solidify. The oily globules were then

separated and dissolved in hot dilute alcohol and the alcoholic solution was kept overnight. Thick needle-shaped crystals separated out. These were separated and the mother liquor on keeping and dilution with water deposited a further quantity of crystals. The crystals thus obtained were further purified by recrystallisation from hot dilute alcohol and they melted at 113°. The substance was identified to be 3-methoxy-4-hydroxy-cinnam-*m*-toluidide. Yield 35.3 per cent.

Found Nitrogen = 4.9%: $C_{17}H_{17}O_3N$ requires 4.94%.

b. *With veratraldehyde*

1. *In the absence of condensing agents.* On heating a mixture of 2 gm. of malon-*m*-toluidic acid and 1.6 gm. of veratraldehyde at 100° for four hours, a pale yellow viscous mass was obtained. This on extraction in the usual manner yielded 0.6 gm. of an acid product which on analysis was found to be 3:4 dimethoxy-benzylidene-malon-*m*-toluidic acid. This melted with decomposition at 230°, Yield 17.6%. Found Nitrogen = 4.21% : $C_{19}H_{19}O_5N$ requires 4.1%.

2. *With a trace of piperidine.* A brown liquid was obtained when a mixture of 1 gm of malon-*m*-toluidic acid, 0.8 gm. of veratraldehyde and 0.1 cc of piperidine were heated at 100° for four hours. This was dissolved in hot dilute alcohol and on cooling a pale yellow oil was obtained. This on cooling in ice solidified. The solid weighed 1 mg. and after repreated recrystallisation from dilute alcohol, melted between 75° and 81°.

Found Nitrogen = 4.61 % : 3:4-dimethoxy cinnam-*m*- toluidide ($C_{18}H_{19}O_3N$) requires 4.71%.

c. *With Piperonal*

1. *Without any condensing agent.* 1.9 gm. of malon-*m*-toluidic acid and 1.5 gm. of piperonal were mixed and kept at 100° for four hours. On extraction in the usual manner, it gave 1 gm. of a pale brown powder. This after recrystallisation from hot alcohol melted with decomposition at 207°C. This was acidic, decolorised

potassium permanganate and bromine water. Found Nitrogen = 4.53% : 3:4-methylenedioxy-benzylidene-malon-*m*-toluidic acid ($C_{18}H_{15}O_5N$) requires 4.31% . Yield 30.7%.

2. *With a trace of piperidine.* On heating a mixture of 1 gm. of malon-*m*-toluidic acid, 0.75 gm. of piperonal and 0. 1 cc of piperidine, for three hours on water-bath, 1.3 gm of a non-acidic substance was formed. After recrystallisation from dilute alcohol, the substance melted at 155°. It was unsaturated and on analysis was found to be 3:4-methylenedioxy-cinnam-*m*-toluidide. Yield 92.5%.

Found Nitrogen = 5.11% : $C_{17}H_{15}O_3N$ requires 4.98%.

The same yield (92.5%) of 3:4-methylenedioxy-cinnam-*m*-toluidide was obtained when the above experiment was repeated, but using a trace of pyridine instead of piperidine. The time of heating however had to be extended to four hours.

Condensation of malon-p-toluidic acid with vanillin, veratraldehyde and piperonal.

a. *With vanillin*

1. *Without any condensing agent.* On heating 2 gm. of malon-*p*-toluidic acid and 1.5 gm. of vanillin for four hours at 100°, a pale brown viscous mass was formed. This on extraction gave 1 gm. of a non-acid substance and about 0.3 gm. of an unsaturated acid. The non-acid product after crystallisation from alcohol, melted at 151°. This was analysed and found to be 3-methoxy-4-hydroxy-cinnam-*p*-toluidide. Yield 35.3%. Found Nitrogen = 4.81% : $C_{17}H_{17}O_3N$ requires 4.94%.

The acid product was purified by crystallisation from alcohol and it melted with decomposition at 210°. It was identified to be 3-methoxy-4-hydroxy-benzylidene-malon-*p*-toluidic acid. Yield 9.2%. Found Nitrogen = 4.43%. $C_{18}H_{17}O_5N$ requires 4.28%.

In another experiment when the heating was at 80°, the yield of the acid product rose to 12.2 per cent. and the yield of the non-acid product was only 28.2 per cent.

2. *With a trace of pyridine.* When a mixture of vanillin, malon-*p*-toluidic acid and pyridine (1:1:0.15 mol.) was heated at 100°, 63.6 per cent. yield of 3-methoxy-4-hydroxy-cinnam-*p*-toluidide was obtained.

b. *With veratraldehyde*

1. *Without any condensing agent.* 2 gm. of malon-*p*-toluidic acid and 1.65 gm. of veratraldehyde when heated together at 100° for four hours, gave on extraction 0.7 gm. of a white unsaturated acid. This acid was purified by repeated crystallisations from alcohol. The pure product melted at 232° (d). Analysis showed it to be 3:4-dimethoxy-benzylidene-malon-*p*-toluidic acid. Found Nitrogen=4.32% : $C_{19}H_{19}O_5N$ requires 4·1. %.

2. *With a trace of piperidine.* 1.4 gm. of 3:4-dimethoxy-cinnam-*p*-toludide was formed when 1 gm. of malon-*p*-toluidic acid, 0.8g. of veratraldehyde and 0.1 cc of piperidine were heated on water-bath for two hours. This could be purified from alcohol. It melted at 136°. Found Nitrogen=4.89%. $C_{18}H_{19}O_3N$ requires 4.71%.

c. *With Piperonal*

1. *Without any condensing agent.* On heating an equimolecular mixture of piperonal and malon-*p*-toluidic acid, at 100° for 4 hours and then extracting in the usual manner, a mixture of 15.4 per cent. of 3:4-methylenedioxy-benzylidene-malon-*p*-toludic acid and 10.6 per cent. of 3:4 -methylenedioxy-cinnam-*p*-toluidide was obtained. These compounds were separated and they melted at 208° (d) and at 167° respectively. Found : Nitrogen = 4.6%. 3:4-methylenedioxy-benzylidene-malon-*p*-toluidic acid, ($C_{18}H_{15}O_5N$) requires 4.31%. Found : Nitrogen = 5.28%. 3:4-methylenedioxy-cinnam-*p*-toluidide ($C_{17}H_{15}O_3N$) requires 4.98%.

SUMMARY

Malon-*o*,-*m*- and *p*- toluidic acids were condensed with vanillin, veratraldehyde and piperonal, both in the presence of a trace of an organic base like pyridine or piperidine, as well as in the absence of condensing agents. The organic bases used were found to catalyse the reactions. In addition to their catalytic influence, they induced decarboxylation of the products. The three aldehydes tried gave two products in each case (a) the corresponding benzylidene-malon-*o*-, *m*- or *p*-toluidic acid and (b) the corresponding cinnam-*o*,-*m*- or *p*-toluidide. As expected, vanillin was the least reactive among the three aldehydes. When the hydroxy group in vanillin was methylated the condensation proceeded well.

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BIOCHEMICAL CHANGES IN THE PREPARATION OF COMPOSTS

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After the elucidation of the fundamental principles underlying the preparation of artificial manure by Hutchinson and Richards (1910), attempts were made all over the world for utilizing agriculture and town wastes as raw materials for compost. In India several workers employed the preparation of synthetic organic manure from farm, domestic and municipal wastes and evolved different methods for composting these materials.

In 1930, Pillai and others attempted to utilize *Lantana* as a raw material for making manure. Later Howard and Wad (1931) evolved the Indore process of composting waste products of agriculture. Jackson and Wad and Panse (1934) modified this method successfully to suit varying climatic conditions by growing suitable legumes on rain composts. Krishnaswami (1934), Tambe and Wad (1935) and Srivastava, Chaturvedi and Rao (1940,42) tried to prepare compost from waste products of sugar industry *e. g.* cane trash, press-mud, bagasse, etc. Rao and Subrahmanyam (1932), Jackson and Wad (1932), Anstead (1932), Fowler (1934), Mieldazis (1934) and Daji and Gode (1947) contributed to the sanitary utilization of sewage sludge, domestic garbage, night soil and other town refuse. Rajgopal, Shrikhande and Subrahmanyam (1936) and Shrikhande (1936) studied the possibilities of applying the Edelmist or the hot fermentation process, originally proposed by Krantz, to the disposal of town refuse in India. Acharya (1939-40) subsequently found that the hot fermentation process was more suited for the composting of street sweepings and night soil.

In 1941 Mayadas and Das advocated extra aeration from the bottom of the pit for quick decomposition.

The different processes of composting plant materials and other refuse thus evolved can be classified under three main groups:

1. Aerobic fermentation as in the Indore method.
2. Extra-aerobic fermentation as advocated by Mayadas and Das.

3. Aerobic fermentation followed by anaerobic decomposition as in the hot fermentation or the Edelmist process.

A comparison under laboratory conditions was made of the above three processes, in order to study the extent of chemical changes undergone by the organic matter during decomposition.

EXPERIMENTAL

Decomposition was conducted in large wooden boxes specially made for the experiments. In the extra-aerobic method of Maydas and Das (1941), one side of the box was elevated and V-shaped channels leading to an air hole were constructed to ensure the entry of air from the bottom. For the anaerobic method the boxes were sealed and the fissures smeared with mud to ensure anaerobic conditions.

Chopped green jowar (*Andropogan sorghum*) stalks were used for composting. An inoculum consisting of fresh cattle dung, urine earth, old compost and wood ash in the following proportion was used as a source of nitrogen and micro-organisms.

Fresh cattle dung	50 parts.
Urine earth	35 parts.
Old compost	10 parts.
Wood ash	5 parts.
Water	1000 parts.

Initial moisture of the heaps was adjusted to about 60% after adding the slurry. Attempts were made to maintain this moisture content by frequent stirring and adding necessary moisture. The material for the "Edelmist" process was sealed after allowing it to ferment aerobically for a week till the maximum temperature was attained.

At frequent intervals the total material was weighed and samples removed, oven dried and milled before analysis except for the determinations of total nitrogen and mineral nitrogen. The results are expressed as percentage on oven dry basis on original material.

TABLE 1

Organic matter initially present and finally recovered

TREATMENTS	Incubation period days	Total organic matter gms.	Organic carbon gms.	Total nitrogen gms.	C : N	Ether extract gms.	Water Extract gms.	Hemicellulose gms.	Cellulose gms.	Lignin gms.	Crude fibre gms.
Extra-aerobic	0	5641	3430	137·8	24·88	58·04	1320	803·4	472·1	856·3	1620
(Mayadas & Das)	210	2789	1726	109·8	15·58	10·06	731·0	146·7	92·12	593·2	499·2
Aerobic	0	5724	3418	138·8	24·61	59·16	1444	862·0	483·8	905·5	1567
(Indore)	210	3048	2025	117·3	17·29	13·90	842·9	253·0	143·5	728·1	576·5
Hot Fermentation	0	5470	3430	133·6	25·68	52·88	1201	807·1	485·0	834·5	1575
(Edelmist)	210	3355	2109	115·1	18·40	19·37	824·8	391·9	159·9	595·0	720·6

Fig. 1

CHANGES OF TOTAL ORGANIC MATTER DURING DECOMPOSITION

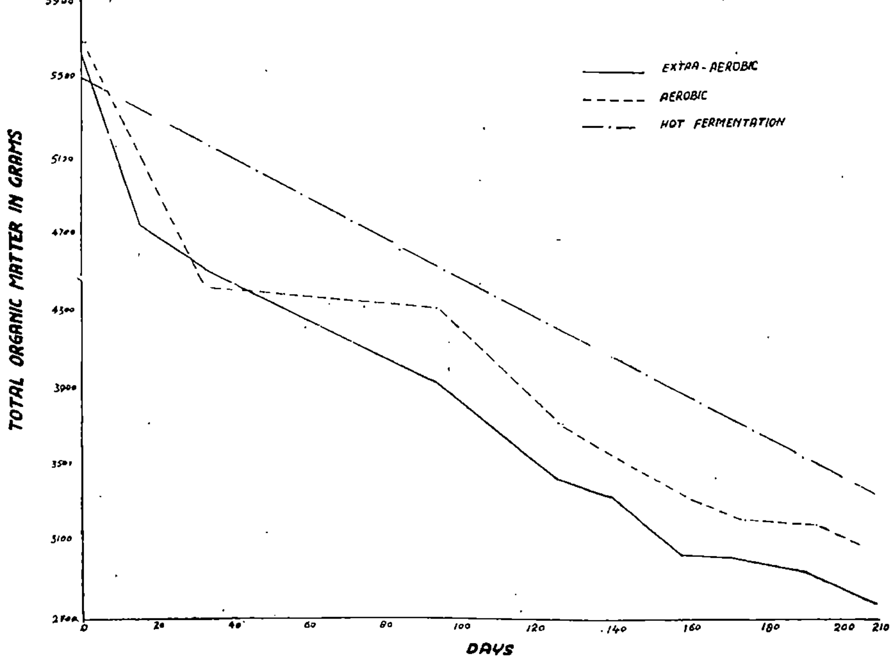
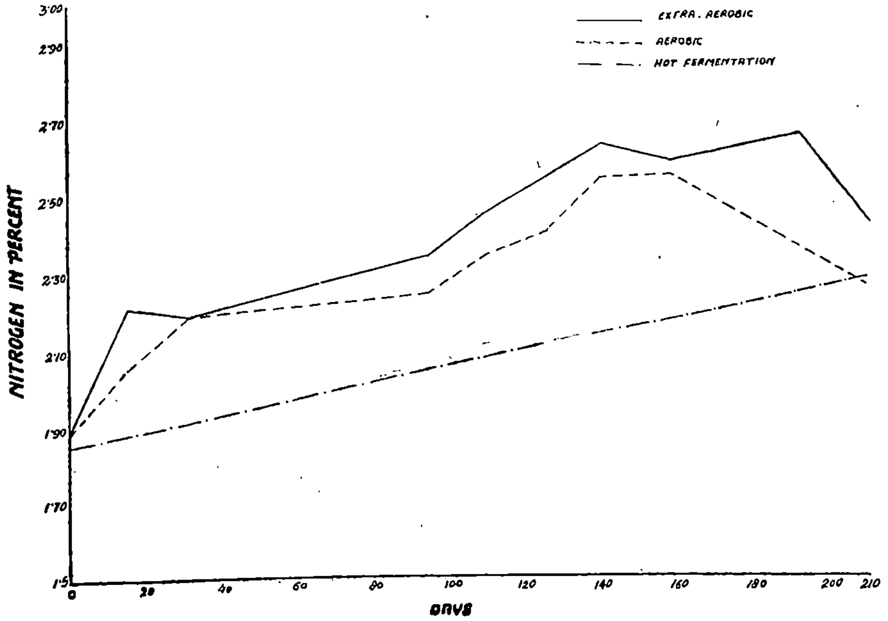


Fig. 2

CHANGES IN THE NITROGEN CONCENTRATION DURING DECOMPOSITION



The analytical methods of Ashworth (1942) were adopted for analysis. The following determinations were made in duplicate.

1. Moistrure.
2. Loss on Ignition.
3. Ether-extract petroleum ether, B. P. 40-60 sp. gr. ·668 to ·690.
4. Water solubles.
5. Hemicelluloses.
6. Cellulose.
7. Lignin.
8. Crude fibre by British Official Method (Wright 1949)
9. Carbon by modified Walkley and Black's method (1935).
10. Total nitrogen by the improved Kjeldähl's method.
11. Nitrate colorimetrically by phenol-di-sulphonic method (Harper, 1924).
12. Nitrites by Greiss colorimetric method.
13. Ammonia by distillation with heavy magnesium oxide.

The initial and final analysis are given in Table I and the rest of the analysis are presented graphically.

CHANGES IN THE TOTAL ORGANIC MATTER

The loss in organic matter as judged by the loss on ignition reached its maximum during the first six weeks as seen from graph I. Such rapid loss in the beginning is undoubtedly due to the decomposition of sugars and other water soluble constituents.

After about 210 days 51 per cent. of the organic matter was decomposed in the extra-aerobic process and 47 per cent. and 38% under aerobic and hot fermentation processes respectively. Such a sequence of oxidation has also been reported by other workers like Waksman (1938), Acharya (1935), Guha-Sircar, De and Bhowmick (1940) and Karim (1948). The decomposition was, however, not so great as recorded by these workers. This is probably due to the maturity of jowar plants. Waksman (1938) has also stressed that the state of maturity is an important factor in decomposition.

CARBON AND NITROGEN TRANSFORMATIONS

The losses of the total organic carbon were proportional to the total organic matter lost.

There is an apparent increase as indicated in graph 2 in the nitrogen content due to the loss of organic matter under all the conditions of composting. This increase of nitrogen continued till 160 days after which there was a fall due to the loss of nitrogen.

The figures of total nitrogen content actually present as in graph 3, however, present a different picture. The nitrogen content which was more or less constant in the early stages dropped down continuously towards the end, the loss of nitrogen being 20% in the extra-aerobic, 16 per cent. in the aerobic and 13 per cent. in the hot fermentation process after 210 days. Greater loss of nitrogen thus occurred under aerobic conditions than under anaerobic ones. The loss of nitrogen under aerobic conditions may be occurring mostly in two ways:

(1) Volatilization of ammonia.

(2) Oxidation of ammonia to nitrogen

$4\ NH_3 + 3\ 0_2 = 6\ H_20 + 2\ N_2$

The losses in the hot fermentation process may be due to denitrification—nitrates being reduced to nitrites and this nitrite acting on amino acids liberating elemental nitrogen.

Similar losses in nitrogen have been reported by Howard (1931), Desai (1933), Fowler, (1934), Raju (1936) and others. Russell and Richards (1917) observed losses of nitrogen to the extent of 33 per cent. in the aerobic decomposition of farm yard manure. They have shown that practically no loss of nitrogen occurred in anaerobic decomposition and the whole initial nitrogen was recovered within the error of experiment, while in aerobic conditions the farm yard manure suffered sufficient loss of nitrogen. They have attributed this loss of nitrogen either due to volatilization of ammonia or due to the evolution of nitrogen in the gaseous form due to alternate oxidation and reduction, nitrates being formed at one time and reduced at another.

A large amount of work has been done on the ammonification and nitrification of plant materials. Plant materials with wide C:N ratio undergo decomposition, extensive carbon dioxide formation and very little ammonia formation is observed. As a result the C : ratio narrows down and below 20 ammonia formation starts. As in this case in graph 4 the ratio was not wide

Fig. 3.

CHANGES IN THE TOTAL WEIGHT OF NITROGEN DURING DECOMPOSITION

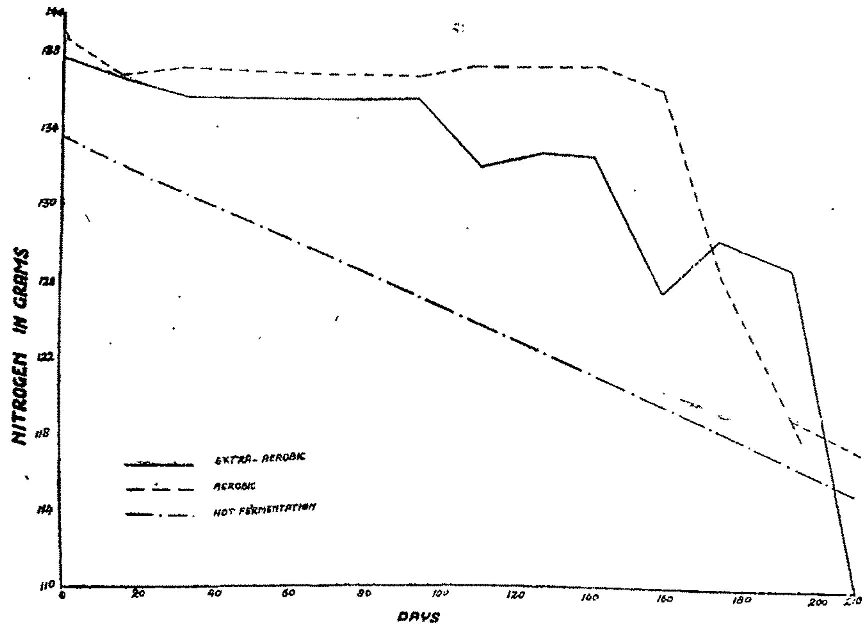
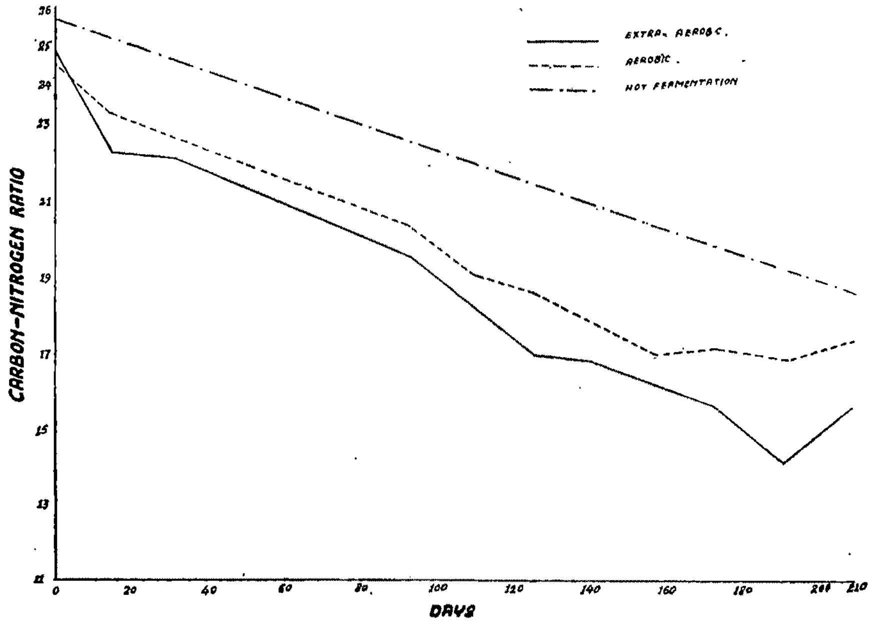


Fig. 4.

CHANGES IN THE CARBON-NITROGEN RATIO DURING DECOMPOSITION.



(about 25) and in the beginning the material nitrified quickly. After about seven months the ratio had reached 16.8 in aerobic and 14.2 in extra-aerobic and 18.4 in anaerobic composts. The attainment of lowest C:N ratio in extra-aerobic compost shows a vigorous decomposition and mineralization of organic matter due to better aeration. This observation is in confirmity of that of Niklewski (1910) who found that nitrite bacteria find conditions in stable manure very favourable for their development so long as aeration is good and the manure is not saturated with urine. The following figures further support this view:

	Treatments		
Nitrogen	Extra-aerobic	Aerobic	Hot fermentation
Ammonia	4·216 mg.	5·168 mg.	32·700 mg.
Nitrite	3·822 mg.	4·802 mg.	1·038 mg.
Nitrate	686·900 mg.	337·700 mg.	258·700 mg.
Total available	694·938 mg.	347·270 mg.	292·438 mg.

Nitrate nitrogen is maximum under extra-aerobic conditions and minimum under anaerobic conditions. Similarly ammonia has accumulated more in anaerobic compost than in extra-aerobic and aerobic ones. It is thus apparent that nitrogenous substances under anaerobic conditions nitrify to a lesser extent than under aerobic conditions.

As indicated earlier, considerable amount of nitrogen was lost in extra-aerobic composts with maximum nitrate accumulation. It appears therefore that nitrogen losses are somehow related to nitrate formation. The probable explanation according to Russell and Richards (1917) is "In the mixed aerobic and anaerobic conditions obtained, when air diffuses into manure there is a loss of nitrogen which has been traced to an evolution of nitrogen gas. The total amount of decomposition is greater in aerobic composts than under anaerobic conditions : it is possible that more ammonia is formed, but if so, it does not survive."

The mixed aerobic and anaerobic conditions are likely to prevail during the periodic "stirrings" given to the compost material.

Recently this fact has also been emphasised by Fowler (1947) in explaining the losses of nitrogen during composting.

CHANGES IN FATS AND WAXES

The fats and waxes as denoted by the ether-extract figures fluctuated slightly tending towards a decrease. Probably along with decomposition synthesis of fats has also taken place during composting. Ashworth (1942) suggested that the increase in the fat content during decomposition may be due partly to the great relative break down of carbohydrates and partly to actual synthesis. There is also some evidence of synthesis of fats from carbohydrates by moulds and fungi [Haehn and Knitof (1925) Barber (1929)]. Hence when fungi are active during decomposition fats may be synthesised.

The relative losses of fats and waxes in different treatments are extra-aerobic 82.7%, aerobic 76.% and hot fermentation 63.4. As is evident, fairly extensive decomposition of fats and waxes, which are comparatively resistant, has taken place in the extra-aerobic compost.

CHANGES IN WATER SOLUBLE ORGANIC MATTER

Water extract comprises the various sugars, degradation products of polysaccharides and proteins. After 210 days of composting about 45 per cent. (extra-aerobic), 42 per cent. (aerobic) and 31 per cent. (hot fermentation) of water soluble organic matter was lost.

The total losses in water solubles are not so conspicuous as of the other constituents of organic matter. This may be partly due to the fact that in the later stages of decomposition the more complex and insoluble constituents may have undergone degradation with the resultant products more soluble in water and partly as Waksman and Tenny (1929) have pointed out that the hot water soluble constituents decompose slowly and even tend to accumulate during the later stages of decomposition, no doubt, because of production of synthesised microbial cell substance containing substances soluble in hot water.

Fig. 5

CHANGES IN THE FATS AND OILS DURING DECOMPOSITION.

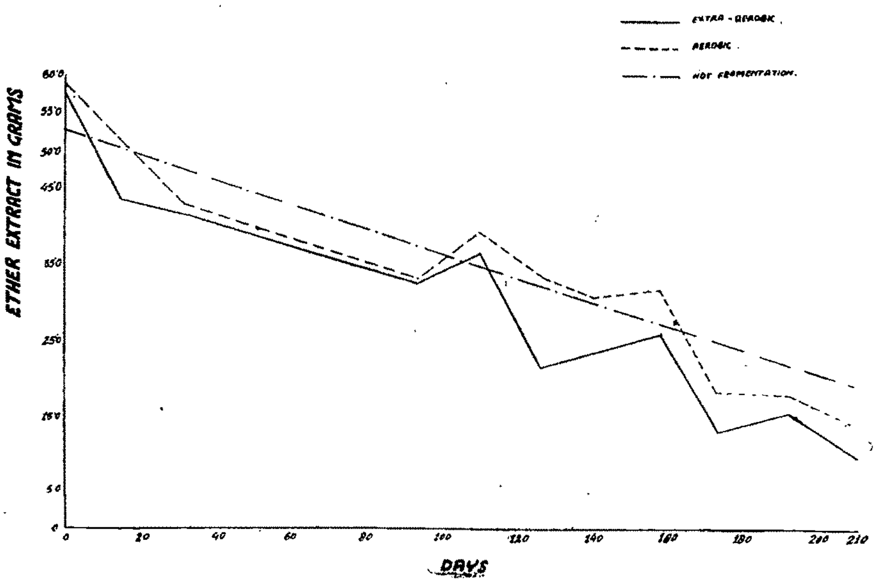
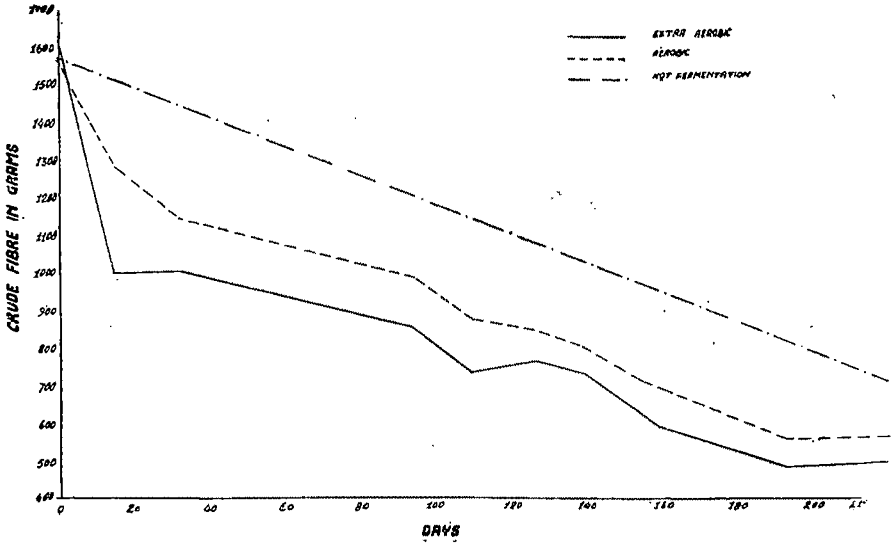


Fig. 6.

CHANGES IN THE CRUDE FIBRE DURING DECOMPOSITION



CHANGES IN HEMICELLULOSES AND CELLULOSE

Hemicelluloses and celluloses content varies according to the nature of maturity of plants. Jowar contained 11·2% hemicellulose and 6·8 per cent. cellulose. About 82 per cent of hemicelluloses and 80·5 per cent. cellulose* and 72 per cent. cellulose and in hot fermentation 51% hemicelluloses and 67 per cent. cellulose decomposed in 210 days. Thus a fairly extensive decompositon of both hemicellulose and cellulose has taken place under aerobic conditions.

CHANGES IN THE LIGNIN & LIGNOCELLULOSE COMPLEX (CRUDE FIBRE)

Lignin, generally next to hemicellulose and cellulose, is the most abundant constituent of plant tissues. Jowar contained about 12 per cent. lignin.

It is generally accepted that lignin is more resistant to the attack of micro-organisms than other groups of plant constituents. Hence an apparent increase in the lignin content was observed (from 12.32 per cent to 14·02 per cent. after 210 days) as the decomposition of the more readily available complex proceeded further. Waksman and Tenny (1929) and Ashworth (1942) have similarly recorded an overall increase in lignin. However about 31 per cent. in extra-aerobic, 24 per cent. in aerobic and 28 per cent. in hot fermentation of the total lignin content was lost after 210 days of composting. It is therefore clear that lignin is also lost during composting of plant materials specially under good aerated conditions.

Phillips, Waite and Smith (1930) state that under suitable conditions the lignin, as found in the lignified plant materials (corn stalk etc.) decompose. Waksman and Tenny (1929) have also shown that under aerobic conditions lignin gradually decomposes, not so rapidly as other chemical complexes but still in a very definite manner.

In the plant tissues lignin is present in a pure state only to limited extent, but largely in the form of compounds with cellulose.

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*80·5% was lost in extra-aerobic compost ; in aerobic 71% hemicelluloses.

It is fairly well known that abundance of this complex hinders the rapid mineralization of organic matter. Hence the study of this portion of organic matter is important. Jowar was rich in the complex about 20 to 22 per cent. The graph (6) shows that crude fibre has decomposed rapidly during earlier period especially under extra-aerobic conditions and afterwards also it has undergone rapid and continuous losses. About 69% of the crude fibre was lost under the extra-aerobic condition and 63 per cent. and 54 per cent. under aerobic and anaerobic conditions respectively. Thus though the lignocellulose complex is resistant to decomposition appreciable amounts of this complex has been lost in the extra-aerobic process.

ACKNOWLEDGMENTS

My grateful thanks are due to Dr. B. K. Mukerjee the then Professor of Chemistry for initiating and guiding this work and to Dr. J. G. Shrikhande, Professor of Chemistry in preparing and criticising the manuscript.

SUMMARY

1. Various biochemical changes taking place during the decomposition of the organic matter while preparing composts were studied under extra-aerobic, aerobic and anaerobic conditions.
2. Analytical methods described by Ashworth were adopted.
3. The samples for analysis were removed fortnightly.
4. The total organic matter and organic carbon decomposed rapidly during early periods of composting and subsequently underwent a slow decomposition. Maximum losses took place in the extra-aerobic compost.
5. An apparent increase in the concentration of total nitrogen was observed during most of the part of composting period and a decrease in the end. However, the total nitrogen content figures denoted losses under both extra-aerobic and aerobic conditions. Under anaerobic conditions most of the nitrogen was conserved.
6. The available nitrogen especially the nitric nitrogen was more in the extra-aerobic compost than in the aerobic & hot fermentation composts. Also the lowest C/N ratio was attained earliest in the extra-aerobic compost.
7. The changes in the fats and oils though showing a decreasing tendency were not regular. Fairly extensive decomposition of fats and oils was observed under aerobic conditions especially under extra-aerobic one.
8. Water solubles suffered an appreciable loss during composting, especially under extra-aerobic conditions.
9. Celluloses and hemicelluloses decomposed more or less completely especially under-extra-aerobic conditions.
10. Lignin underwent a comparatively slow decomposition, but still appreciable amount of lignin was lost in the aerobic composts. An apparent increase in the concentration of lignin was also observed.
11. The lignocellulose complex or crude fibre decomposed fairly steadily and rapidly, especially under extra-aerobic conditions.

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EFFECT OF 2,4-D ON YIELD OF WHEAT

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The method of weed control in a crop field by various formulations of 2,4-D is based on the relative resistance of the plants to the weedicidal spray. In such spray operations the aim is to use a quantity of 2,4-D, which will kill most of the weed species but not seriously damage the grain crop. Though the cereals are generally considered resistant to 2,4-D, yet under some conditions they may be more or less affected. It is thus essential to know the relative susceptibility of both weeds and crop at different stages of development.

MATERIALS AND METHODS

The study was conducted at B. R. College Experimental Farm, Bichpuri, Agra, during the crop (wheat) season of 1951-52. The treatments followed were three concentrations of 2,4-D sprays, hand weeding and check (control) at three stages of wheat growth. The chemical used was the commercial preparation Fernoxone (containing 80% 2,4-D as sodium salt, of 2, 4-Dichlorophenoxyacetic acid) as an aqueous spray. The three concentrations were 3.25, 4.88 and 6.50 pounds per acre, dissolved in 100 gallons of water. The application of spray was made with a sprayer at six weeks, nine weeks and twelve weeks after sowing (i. e. tiller, boot and bloom stages of wheat). At each of three stages the hand weeded plots were weeded shortly after the chemical treatments carried out. A complex randomised block design of layout was followed with four replications and 15 treatments, making sixty plots in all of 4′ x 4′ size. The seed-rate used in the experiment was 40 seers per acre. The variety of wheat was Pb 591.

RESULTS AND DISCUSSION

Count of the weed population indicated that there was a fairly uniform stand of weeds in all the plots. The weeds competing with the wheat crop were *Chenopodium album*, *Asphodelus tenui-*

folius, *Melilotus indica*, *Convolvulus arvensis*, *Anagallis arvensis*, *Vicia* sp., *Fumaria parviflora* and *Cyperus rotundus*. The effect of the chemical was observable on the weed plants 12 hours after spraying and was marked with noticeable bending and twisting of leaves and stem after twenty-four hours. While the weeds under all the concentrations of 2,4-D showed injury, those under the highest concentration showed the most and those under the lowest one, the least injury. Three weeks after the treatment nearly all the weeds (except *Cyperus rotundus*) in the 2,4-D-treated plots were killed. This period between spraying and death of weeds was shortened with the third spraying when there was an appreciable rise in the atmospheric temperature. When the grain had reached maturity, the plots were harvested separately, threshed, winnowed and grain was weighed.

TABLE 1. Yield of wheat as affected by different weeding treatments applied at different stages of growth.

Treatments	Grain yield (gm.) per plot (4′x4′) Stages of development			
	Tillering	*Boot*	*Bloom*	Mean
2, 4-D @3.25 lbs./ acre	160.50	162.25	146.25	156.33
" @4.88 "	178.75	166.75	136.75	160.75
" @6.50 "	141.25	146.75	126.75	138.25
Hand weeded	191.50	203.25	170.50	188.41
Check	136.25	138.00	137.00	137.08
Mean	161.65	163.40	143.45	

The grain yield data were statistically analysed and it was observed that the differences between the chemical treatments, hand weeding and check was significant (5%), while treatments at different stages and interaction between stages and rates of 2,4-D and hand weeding were not significant. The summarized results are given in Tables 2 and 3.

TABLE 2. Mean yield of grain in gms. per plot (4'x 4') of wheat treated with 2,4-D at three rates, hand weeding and check.

Treatment	Grain yield in gms. per plot (4'x4')	C. D.	
2, 4-D @3.25 pounds/acre	156.33	40.16	5%
" @4.88 ,,	160.75		
" @6.50 ,,	138.25		
Hand weeding	188.42		
Check	137.08		

It is evident that the hand weeded plots showed superiority over the rest. The yield was significantly more than the check and the plot treated with 6.50 pound-rate of 2,4-D but the differences between hand weeded and 4.88 pound-rate and hand weeded and 3.25 pound-rate were not significant. It is also clear that the differences among the chemical treatments or their differences from check were not significant, though the first two concentrations showed better effects.

The hand weeding made the crop plant free from competition with weeds for nutrient and moisture. The spraying with 2,4-D also likewise removed the weeds by killing them slowly. The hand weeding had an additional beneficial effect of improving the soil conditions through the resulting hoeing. The higher concentration of 6.50 pound-rate showed lower yield, though not significantly, when compared to the other two lower concentrations. This might have been caused by some injury due to the chemical. A decrease in yield of a strain of wheat, with higher concentration was observed earlier by Klingman (1) and McNeal (2) and recently by Overland and Rasmussen.(3).

TABLE 3. Mean yield of grain in gms. per plot (4' x 4') of wheat under weeding treatments overall applied at three stages of plant growth.

Treatments	Grain yield in gms. per plot (4' x 4')
Six weeks after sowing	161.6
Nine weeks after sowing	163.4
Twelve weeks after sowing	143.3

The treatments of spraying and weeding showed some promising effect in earlier stages up to nine weeks but afterwards marked decrease was noticed. Tingey (4) also observed that later treatments coincide with the boot and bloom period of the crop where there is every chance of injury.

Summary and conclusions

A mixed stand of weeds and Pb 591 wheat was sprayed with 2,4-D at 3.25 pound-rate, 4.88 pound-rate and 6.50 pound-rate and hand weeded with 'khurpi' at three stages of crop growth (six weeks, nine weeks and twelve weeks after sowing). All the weeds, except *Cyperus rotundus*, were killed within three weeks of spray.

Plots receiving the treatment of hand weeding showed significant increase in yield over plots sprayed at 6.50 pound-rate and check. There was no significant difference among the three concentrations and check. Both the 3.25 pound-rate and 4.88 pound-rate were similar and superior to 6.50 pound-rate. Spraying and weeding treatments given at six weeks and nine weeks of crop growth were similar and superior to treatments given at twelve week stages though the differences were not statistically significant.

Acknowledgment

My grateful thanks are due to Professor Dr. N. K. Anant Rao, M. Sc., Ph. D., under whose guidance these investigations are being done.

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EFFECT OF PHOSPHATE MANURING OF BERSEEM ON ITS YIELD AND QUALITY

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Experiments during the last quarter of a century suggest that legumes have considerable power of utilizing the phosphate and that they show much response to phosphate fertilizers. Parr and Bose (1, 2, 3) consider that since legumes add valuable nitrogen to the soil and since the amount of added nitrogen increases with the increase in the legume yield, it would appear that phosphate manuring offers a method not only of increasing the yield of legume crops and thus protein production but also of supplying Indian soils with the much needed addition of nitrogen for the benefit of crops. Desai and Sen (4) have reported the results of drain-gauge experiments conducted at Pusa (Bihar) for 30 years, which show that the growth of a legume crop like sunn-hemp did not enrich the soil with nitrogen, if the over-ground portion of the crop was removed from the field. Acharya, Jain and Jha (5) have reported that "Agronomic experience of several centuries has shown the advantage of growing legumes in the rotation, for maintaining soil fertility and crop yields. In fact, in some cases, as with alfa alfa or the clovers, soil fertility may be actually built up to a high level by the introduction of legume crops in rotation, even though the legume may be cut for hay or harvested as cuttings from time to time and removed from the land."

METHOD AND MATERIAL

An experiment was laid [illegible] to study the influence of varying doses of phosphate (0, 66, 132, 198 and 264 lbs of P_2O_5 per acre) at two levels of irrigation (low and high) on berseem crop sown at three different seed rates (7, 10 and 13 seers per acre). Irrigation was applied at the rate of 2.5 acre inch and 5 acre inch respectively for low and high levels of irrigation. In all nine irrigations were given to the crop. The interval between irrigations ranged from 15 to 30 days depending on the condition that prevailed. The experiment was conducted at Balwant Rajput College Experimental Farm, Bichpuri, Agra. during the winter season of 1949-50. The field was laid out according to single split plot design with three replications considering two levels of irrigation as main treatments. The net plot size was 1/100th of an acre. Following the normal practice of the locality three cuttings of the crop were taken and then the crop was left for seed production. Phosphate was applied in the form of superphosphate (18.5% P_2O_5) on 27th October, 1950 on the surface and was mixed with soil by harrowing. The inoculated seeds at given rates were sown on 2nd November, 1950. The mechanical and chemical composition of surface soil (0-9″) is given below:

TABLE I.

Coarse sand	0.26%
Fine sand	55.34%
Silt	22.07%
Clay	18.88%
Nitrogen	0.04%
Total P_2O_5	0.09%
pH.	8.55

EXPERIMENTAL FINDINGS

The yield of green fodder [illegible]reasd with successive cuttings and the highest yield was obtain[illegible] in the third cutting. Among the treatments the doses of phosphate produced the most pronounced effect. The statistical analysis of the data for each cutting indicated that application of phosphate significantly (1%) increased the yield in each cutting. Seed rate had significant effect only at first cutting when the higher seed rate of 13 seers gave higher yield. The levels of irrigation had significant effect only at second cutting.

TABLE II

Effect of phosphate levels on the average yield (Mds.) of green fodder per acre at different cuttings

Treatment	1st cutting 51 days after sowing			2nd cutting 97 days after sowing			3rd cutting 144 days after sowing		
	Yield (Mds.) per acre	Increase over control	Response in srs. per lb. P_2O_5	Yield (Mds.) per acre	Increase over control	Response in srs. per lb. P_2O_5	Yield (Mds.) per acre	Increase over control	Response in srs. per lb. P_2O_5
No manure—P_0	16.34	...	...	114.90	...	...	225.74	...	...
66 lbs. P_2O_5—P_1	22.90	6.56	3.98	166.06	51.16	31.00	302.49	76.75	48.03
132 „ „ —P_2	25.93	9.59	2.90	189.80	74.90	22.70	332.04	106.30	32.20
198 „ „ —P_3	32.74	16·40	3.31	197.50	82.60	16.69	355.03	129.29	26.1
264 „ „ —P_4	30.06	13.72	2.08	204.80	89.9	13.60	363.41	137.67	20.8
Critical Diff.	5%—5.0 1%—6.6			5%—7.15 1%—9.86			5%—21.42 1%—28.48		

The above table indicates that all the doses of phosphate significantly increase the yield over control. The differences among the effects of P_3 and P_4 are non-significant.

In the first cutting highest yield was obtained under P_3 (198 lbs. of P_2O_5 per acre) which was significantly (1%) greater than those under P_1 and P_2. In the second and third cuttings the highest yield was obtained under the maximum dose of phosphorus P_4 (264 lbs. P_2O_5 per acre) which was significantly (1%) more than those under P_1 and P_2. In the second and third cuttings the response per lb. of P_2O_5 decreased with increasing doses of phosphorus and the highest response per lb. of P_2O_5 was obtained under P_1 which was 31.00 and 48.03 seers respectively for second and third cuttings.

TABLE III

Effect of seed rate on the yield (Mds.) of green fodder per acre at first cutting

Seed rate per acre	Yield (Mds.) per acre	Increase over S_1 in Mds.	Increase over S_1 in%
7 seers—S_1	19.38	...	...
10 seers—S_2	27.34	7.96	41.0
13 seers—S_3	30.07	10.69	55.2
Critical Diff.	5% — 3.86 1% — 5.13		

The yield under S_2 and S_3 was significantly (1%) more than that under S_1. The difference between S_2 and S_3 was non-significant.

TABLE IV

Effect of irrigation levels on the yield (Mds.) of green fodder per acre at second cutting

Irrigation levels	Yield (Mds.) per acre	Increase over I_1 in mds.	Increase over I_1 in %
2.5 acre inches —I_1	164.08	...	...
5.0 acre inches —I_2	185.10	21.02	12.8
Critical Diff.	5% — 13.29 1% — 30.66		

The yield under I_2 was more than that under I_1. The difference was significant at 5% level.

The effect of treatments on the total yield of green fodder of all the three cuttings was statistically examined. It was observed that the effect of phosphate was significant at 1% level while that of seed rate at 5%. Other treatments were non-significant. The effect of the significant treatments are summarized below.

TABLE V

Effect of phosphate levels on the total yield (Mds.) of green fodder per acre

Treatment	Yield (Mds.) per acre	Increase in yield in mds.	Increase in yield in %	Response in seers per lb. P_2O_5
No manure—P_0	357.02	...	...	...
66 lbs. P_2O_5—P_1	491.46	134.44	37.66	81.48
132 lbs. P_2O_5—P_2	457.78	190.76	53.43	60.23
198 lbs. P_2O_5—P_3	585.31	228.29	63.94	46.12
264 lbs. P_2O_5—P_4	598.29	241.27	67.58	36.56
Critical Diff.	5% — 23.08			
	1% — 31.08			

All the levels of phosphate significantly (1%) increased the yield over control. Both P_3 and P_4 were significantly better than P_1 and P_2. The difference between P_3 and P_4 was non-significant.

The response per lb. of P_2O_5 decreased with increasing levels of P_2O_5.

TABLE VI

Effect of seed rate on the yield (Mds.) of total green fodder per acre

Seed rate per acre	Yield (Mds.) per acre	Increase in yield in mds.	Increase in yield in%
7 seers—S_1	502.157	...	...
10 seers—S_2	524.168	22.011	4.40
13 seers—S_3	521.592	19.339	3.85
Critical Diff.	5% — 17.88		
	1% — 24.08		

The yield under S_2 and S_3 was significantly (1%) more than that under S_1. The difference between S_2 and S_3 was non-significant.

Representative samples of third cutting were drawn from all the 90 plots and mixed together treatmentwise. These samples were dried in oven at 100° C and analysed for nitrogen by Gunning Kjeldhal's method (A. O. A. C. 6th edition, 1945, p. 28). The nitrogen percentage multiplied by 6.25 gave the crude protein percentage in the dry matter.

The following table gives the nitrogen and protein percentages, the total dry weight per plant and the total protein production per plant.

TABLE VII

Treatment	Percentage of		Dry weight (gms.) per plant	Total protein (gms.) per plant
	Nitrogen	Protein		
No manure—P_0	3.23	20.19	7.65	1.54
66 lbs. P_2O_5—P_1	3.10	19.38	14.70	2.85
132 ,, ,, —P_2	3.03	18.94	18.67	3.54
198 ,, ,, —P_3	3.19	19.94	21.22	4.23
264 ,, ,, —P_4	3.36	21.00	23.96	3.03

The percentage of nitrogen and protein decreased with increased supply of phosphorus except under P_4 where it was slightly higher. But the total production of protein per plant calculated on dry weight basis increased with increasing supply of phosphorus. As the yield of green fodder under phosphate levels is very high against control the total protein production per acre will be higher than those under control.

SUMMARY

The paper gives the main results of an experiment on effect of phosphate manuring of berseem on its yield and quality.

1. The yield of green fodder increased with the application of phosphate.

2. The effect of phosphate was noticed from the very beginning, even in the first cutting increased yield was obtained due to phosphate application.

3. The percentage of nitrogen and protein in plants decreased with increased application of phosphate, but the total production of protein per plant on dry weight was more.

ACKNOWLEDGMENTS

Our thanks are due to Dr. N. K. Anant Rao, Professor of Agronomy, B. R. College, Agra, for his keen interest and valuable suggestions in completing the work and to Mr. M. D. Dandawate for help in statistical calculations.

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CONTRIBUTIONS TO OUR KNOWLEDGE OF FIG INSECTS (CHALCIDOIDEA : PARASITIC HYMENOPTERA) FROM INDIA*

III—DESCRIPTIONS OF THREE NEW GENERA AND FIVE NEW SPECIES OF SYCOPHAGINI, WITH NOTES ON BIOLOGY, DISTRIBUTION AND EVOLUTION.†

By K. J. JOSEPH, M. SC., *Senior Research Scholar, Government of India, Ministry of Education, School of Entomology, St. John's College, Agra.*

The type specimens of the new forms described in this paper are kept in the collections of the School of Entomology for the time being.

I record here my grateful thanks to Prof. M. S. Mani for facilities for work, help, guidance, encouragement and confirmation of my identifications.

Subfamily SYCOPHAGINI

1. **Sycophagella,** gen. nov.

Female.—Head a little less than one and a half times as wide between the external margins of the eyes than long; ocelli three. Antenna with twelve segments, of which only one (the third) forms a very large ring-joint. Mandible subtriangular, tridentate; maxillary palpus unisegmented; labial palpus unisegmented. Pronotum moderately large ; mesonotum with the scapulae, scutum, scutellum, parascutella and axillae well-developed; parapsidal furrows complete and deep; propodeal spiracles with small rounded peritremes. Fore wing with long postmarginal vein. Fore, mid and hind legs with five-segmented tarsi. Ovipositor about eight times as long as the abdomen.

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†Part I of this Series is appearing in the *Indian J. Ent.*; part II was published in the *Agra Univ. J. Res.* (*Sci.*). **1**: 73-821 (1952).

Male.—Head depressed, about twice as long as wide, with a division of the head into two parts in a transverse plane—a smaller antero-dorsal region carrying the antennae and the eyes and a longer postero-ventral region carrying the buccal apparatus. Antenna flat and depressed, with four segments in addition to a radicle, scape very large and subcircular. Mandible tridentate. Thorax flat and depressed; pronotum long, with an antero-median longitudinal cleft reaching to about half its length, its lateral margins notched on either side. Fore, mid and hind tibiae provided with many odontoid spines; fore, mid and hind tarsi five-segmented ; fore metatarsus devoid of odontoid spines, mid and hind metatarsi with about three odontoid spines each. Abdomen long, depressed; spiracular processes of the eighth abdominal segment long and narrow.

This genus runs near to couplet No. 2 in Grandi's Key* but is separated from the group of genera leading from it by the single ring-joint of the antennae.

Genotype *Sycophagella agraensis,* gen. et. sp. nov.

Sycophagella agraensis, sp. nov.

Female.—Length 1.65 mm. Head, abdomen, ovipositor valves and all antennal segments, except scape and pedicel, sooty-brown, reinforced by a slight iridescent sheen in the head, scuto-scapular region of mesonotum and abdomen; thorax, scape and pedicel of antenna and ovipositor yellowish-brown, legs melleous ; wings hyaline ; nervures amber, eyes and ocelli pinkish.

Head (Fig. 1) a little less than one and a half times as wide between the external margins of the eyes than long; epistomal margin widely concave in the middle as in figure; lateral margin of head forwards of eyes (gena) two-thirds the longitudinal diameter of the eye; posterior margin of head behind the eyes rounded off at the sides and substraight posteriorly ; eyes large; ocelli large, three in an obtuse triangle ; face rugulose with fine setae. Antenna (Fig. 2) with twelve segments, of which only one (the third) forms a ring-joint, the tenth, eleventh and twelfth fused to form a

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*GRANDI, G. *Boll. Lab. Ent. Bologna,* **1:** 80-81 (1928).

club; scape thickest in the middle, a little over thrice as long as thick, with setae as in figure; second segment one and a half times as long as its maximum thickness, with a few setae ; third segment forms a large ring-joint one and one-third as wide as long; fourth a little longer than thick; fifth and sixth equal, a little longer than thick ; seventh as long as sixth but a little less thick ; eighth as long as seventh but a little less thick ; ninth equal to sixth;

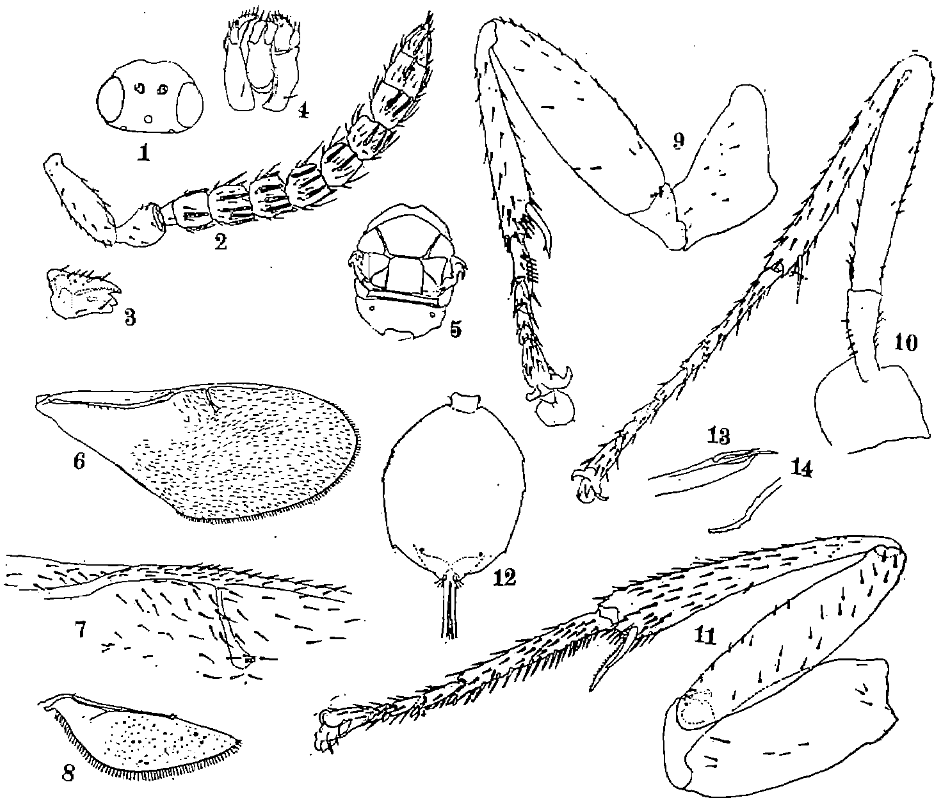

FIG. 1. *Sycophagella agraensis*, gen. et sp. nov., female. Head.
FIG. 2. *Sycophagella agraensis*, gen. et sp. nov., female. Antenna.
FIG. 3. *Sycophagella agraensis*, gen. et sp. nov., female. Mandible
FIG. 4. *Sycophagella agraensis*, gen. et sp. nov., female. Maxillae and labium.
FIG. 5. *Sycophagella agraensis*, gen. et sp. nov., female. Thorax.
FIG. 6. *Sycophagella agraensis*, gen. et sp. nov., female. Fore wing.
FIG. 7. *Sycophagella agraensis*, gen. et sp. nov., female. Details of stigmal vein.
FIG. 8. *Sycophagella agraensis*, gen. et sp. nov., female. Hind wing.
FIG. 9. *Sycophagella agraensis*, gen. et sp. nov., female. Fore leg.
FIG. 10. *Sycophagella agraensis*, gen. et sp. nov., female. Mid leg.
FIG. 11. *Sycophagella agraensis*, gen. et sp. nov., female. Hind leg.
FIG. 12. *Sycophagella agraensis*, gen. et sp. nov., female. Abdomen.
FIG. 13. *Sycophagella agraensis*, gen. et sp. nov., female. Valve, distal part.
FIG. 14. *Sycophagella agraensis*, gen. et sp. nov., female. Tip of ovipositor.

club about two and three-fourths as long as its maximum thickness, segments four to twelve furnished with long sensoria and long setae as in figure. Mandible (fig. 3) subtriangular, longer than broad, tridentate, teeth and setae as in figure. Maxillary palpus (fig. 4) unisegmented, longer than thick, with two acicular setae apically ; labial palpus (fig. 4) unisegmented, twice as long as thick with three acicular setae apically.

Thorax (Fig. 5). Pronotum much wider than long, narrower than propodeum, its lateral margins converging forwards, anterior margin concave in the middle; mesonotum with reticulate punctation, scapula subtriangular, nearly as wide as long, external margins rounded off, scutum smooth, wider than long; parapsidal furrows complete, deep and wide; scutellum nearly as wide as its maximum length; axillae subtriangular, nearly as wide as long; parascutella subtriangular, longer than wide. Metanotum a narrow transverse area. Fore wing (Fig. 6) two and one-sixth times as long as wide, costal cell a little over ten times as long as wide, with about a dozen hairs in its distal half; submarginal vein three and two-thirds the marginal, marginal a little over half the postmarginal, postmarginal over twice as long as the stigmal, stigmal vein (Fig. 7) subclaviform, oblique with respect to the costal margin and tilted towards the distal extremity of the wing with three rounded sensillae on a distal prolongation of the vein as in figure; distal margin of wing rounded off, pubescence on alar cuticle rather long and thin, marginal fringe moderately long. Hind wing (Fig. 8) three times as long as broad, distal extremity of alar cuticle pointed, with three frenal hooks, pubescence minute, marginal fringe long. Fore leg (Fig. 9) with coxa subtriangular, a little over one and a half times as long as wide, with a few setae; trochanter subtriangular, a little longer than wide; femur large, elongate-oval, a little less than thrice as long as its maximum width, with setae as in figure; tibia subclaviform, a little less than six times as long as wide, a little shorter than the femur, with setae and distally with a long bifid spur and a few spines; tarsi five-segmented, armed with setae and spines, metatarsus with about six spines on its ventral sublateral margin set in a comb-like series as in figure and equal to the three following segments combined, fifth distinctly shorter than the metatarsus; pretarsus with a pair of large curved claws and the large empodium. Mid leg (Fig. 10) with coxa as in figure, wider than long; trochanter long, longer than twice its width, with a few setae as in figure; femur about five and a half times as long as wide, with about four rounded sensillae in its proximal region and with setae as in figure; tibia long, subclaviform, a little longer than the femur, about ten times as long as wide, with setae and a single long apical spur; tarsi long, a trifle longer than or equal to the tibia, five-segmented, armed with setae and spines, metatarsus clearly longer than the four following segments combined; pretarsus with a pair of claws and the empodium. Hind leg (Fig. 11) with coxa large and as in figure, two and two-thirds as long as wide, with a few setae; trochanter twice as long as wide; femur long, widest in the middle, a little over four times as long as its maximum width, with setae; tibia long, clavate, distinctly longer than the femur, with many long setae and a pair of apical spurs of unequal lengths; tarsi long but distinctly shorter than the tibia, five-segmented, armed with setae and spines, metatarsus clearly longer than the four following segments united; pretarsus with a pair of claws and the empodium. Propodeum (Fig. 6) wide anteriorly, converging posteriorly, posterior margin emarginate, propodeal tracheal spiracles with small subovoid peritremes situated sublaterally near the anterior margin.

Abdomen as in figure 12, longer than wide; the eighth urotergite with a pair of spiracles provided with small subovoid peritremes; ovipositor very long, over eight times as long as the abdomen; tips of ovipositor valve and of the ovipositor as in figure 13 and 14 respectively.

Male.—Length 2.4 mm. Uniformly yellowish-brown; mandibles, tibiae and certain margins of the body ferrugineous; eyes black.

Head (Fig. 15) depressed, twice as long as wide; lateral margins very faintly converging anteriorly; epistomal margin as in figure 16, with two sublateral rounded prominences separated by an incurvation from a short angular median process, with a few specialized setae; the head is divided in a transverse plane.(Figs.

15&16) into two parts—a smaller antero-dorsal region carrying the antennae and the eyes and a larger postero-ventral region carrying the buccal apparatus*; dorsally the head bears a few small hairy setae. Antenna (Fig. 17) with four segments in addition to a radicle, flat and depressed; radicle wider than long, subtriangular; scape flattened, with a somewhat rounded outline, as long as wide, with a few sensilla-like structures each bearing a small sensory hair; second segment subtriangular, a little longer

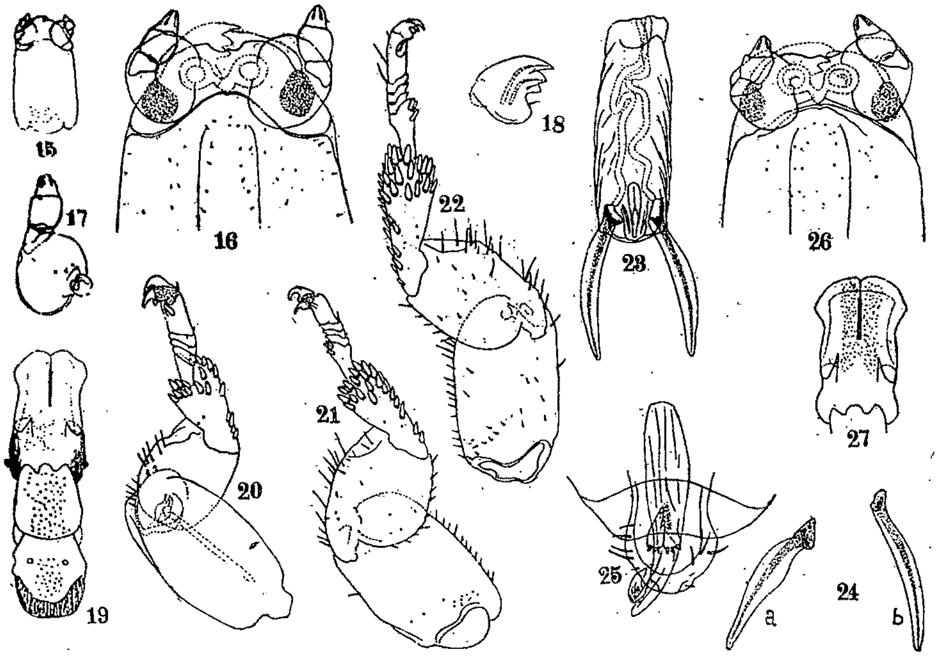

Fig. 15. *Sycophagella agraensis*, gen. et sp. nov., male. Head.
Fig. 16. *Sycophagella agraensis*, gen. et sp. nov., male. Head, highly magnified.
Fig. 17. *Sycophagella agraensis*, gen. et sp. nov., male. Antenna.
Fig. 18. *Sycophagella agraensis*, gen. et sp. nov., male. Mandible.
Fig. 19. *Sycophagella agraensis*, gen. et sp. nov., male. Thorax.
Fig. 20. *Sycophagella agraensis*, gen. et sp. nov., male. Fore leg.
Fig. 21. *Sycophagella agraensis*, gen. et sp. nov., male. Mid leg.
Fig. 22. *Sycophagella agraensis*, gen. et sp. nov., male. Hind leg.
Fig. 23. *Sycophagella agraensis*, gen. et. sp. nov., male. Abdomen.
Fig. 24(a)*Sycophaga brevitarsus*, Grandi, male. Abdominal spiracular process.
Fig. 24(b)*Sycophagella agraensis*, gen. et sp. nov., male. Abdominal spiracular process.
Fig. 25. *Sycophagella agraensis*, gen. et sp. nov., male. Details of ninth and tenth abdominal segments.
Fig. 26. *Sycophaga brevitarsus*, Grandi, male. Head, highyl magnified.
Fig. 27. *Sycophaga brevitarsus*, Grandi, male. Pronotum.

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*Grandi, G. 1929. *Mem. Accad. Sci. Ist. Bologna*, cl. sci fis., (8) **6**: 89-105. 2 pls.

than its maximum width, with a few sensillae as in figure; third segment as long as wide, slightly narrowing towards base, flat, subtrapezoidal; fourth segment depressed, wider than long, converging towards apex, its distal half with 6-8 long sensoria. Mandible (Fig. 18) a little less than one and a half times as long as broad, tridentate, apical tooth longer and more acute than the remaining two, with a few setae as in figure.

Thorax (Fig. 19). Pronotum as in figure, with length a little less than twice its maximum width, with an anterior median longitudinal cleft extending to about half its length, with minute setae; lateral margin of pronotum notched on either side. Mesonotum a little longer than its maximum width in the posterior half, with small hairy setae. Anterior region of metanotopropodeum overlaps the posterior region of the mesonotum, metanotopropodeum one and a half times as long as wide, with propodeal tracheal spiracles and punctiform granulations as in figure, posterior margin rounded off and with a few longitudinal striations. Fore leg (Fig. 20) with coxa long, a trifle longer than twice its maximum width, elongate-oval, subcompressed, with a few setae ; trochanter indistinct; femur short, dilated, a little longer than wide, with many long hairy setae on its outer margin; tibia a little longer than twice its width, about equal in length to the femur, with odontoid spines along its outer margin and in its distal part ; tarsi five-segmented, shorter than the tibia, metatarsus without any odontoid spines distally and equal in length to the three following segments combined, second, third and fourth segments strongly transverse, wider than long, fifth segment one and one-third as long as the metatarsus; pretarsus with a pair of large falciform claws and a diminutive empodium. Mid leg (Fig. 21) with coxa stout, a trifle longer than one and a half times as long as wide, with many long setae along its outer margin; trochanter indistinct; femur dilated, longer than wide, with long setae along its inner margin and short stout setae along its outer margin; tibia shorter than the femur, longer than the fore tibia, a little less than two and a half times as long as its width, with many stout odontoid spines along its entire outer margin and in its distal half; tarsi five-segmented, about equal in length to the tibia, metatarsus with about three odontoid spines in its distal part, a little longer than one and a half times as long as the three following segments combined, segments two, three and four strongly transverse, wider than long, fifth segment longer than the second, third and fourth segments combined, four-fifths the metatarsus ; pretarsus with a pair of large falciform claws and the diminutive empodium. Hind leg (Fig. 22) with coxa one and two-thirds as long as wide, with long hairy setae along its outer margin; trochanter indistinct; femur stout, compressed, one and three-fifths as long as wide; with long hairy setae along its inner margin and thick setae along its outer margin ; tibia shorter than the femur, two and a half times as long as its maximum width, longer than the fore and the mid tibiae, with many large stout odontoid spines along its entire outer margin and in its distal half ; tarsi five-segmented, slightly shorter than the tibia, metatarsus with about three large odontoid spines in its distal part and about one and a half times as long as the three following segments combined, second, third and fourth segments strongly transverse, wider than long, fifth segment longer than the preceding three segments combined, about three-fourths the metatarsus; pretarsus with a pair of large falciform claws and the diminutive empodium.

Abdomen (Fig. 23) large, narrow at base, widening towards apex, thrice as long as wide, entire dorsum of abdomen with conspicuous linear striations ; spiracular processes of the eighth abdominal segment four-fifths the length of the abdomen and about ten times as long as its own maximum width, wide basally, converging towards apex, differently shaped (Fig. 24) than those in *Sycophaga brevitarsus* Grandi ; ninth segment (Fig. 25) with a few very long setae on either lateral side ; tenth with a pair of apically rounded cerci each provided with three tooth-like processes.

Holotype 1 female dissected on slides Nos. 16/30, 16/31, 16/32, 16/33 ; *allotype* 1 male dissected on slides Nos. 16/M—1, 16/M—2, 16/M—3, 16/M—4, 16/M—5, 16/M—6. *Paratypes* females and males in spirit.

Geographical Distribution.—Collected by K. J. Joseph from figs of *Ficus glomerata* Roxb. from foot-ball field, St. John's College, Agra, dated 12th April, 1952.

Observations.—In the figs of *Ficus glomerata* Roxb. from football field, St. John's College, Agra, collected on 12th April, 1952, the following four genera of fig insects were found:–

1. *Ceratosolen fusciceps* Mayr, females and males.
2. *Lipothymus glomeratus* Joseph, females and males
3. *Sycophaga brevitarsus* Grandi, females and males.
4. *Sycophagella agraensis* Joseph, females and males.

The female of *Sycophagella agraensis* Joseph has a superficial resemblance to *Sycophaga brevitarsus* Grandi, but is easily distinguishable on account of its smaller size and colour differences and other characters. Very great difficulty is experienced in distinguishing the males of *Sycophagella agraensis* Joseph from those of *Sycophaga brevitarsus* Grandi, for the males of the two abovementioned insects apparently so closely resemble each other in body form, pattern, colour, and so forth. Both of these have the long spiracular processes at the tips of abdomen. A clue to the separation of the males of the two genera is obtained when the nature of the spiracular processes, their form and shape, in the two genera is closely observed. In *Sycophaga brevitarsus* Grandi, it is as in fig. 24 a. In *Sycophagella agraensis* Joseph it is as in fig. 24b.

Convergent Evolution.—The similarities which the female of *Sycophagella agraensis* Joseph bears to the female of *Sycophaga brevitarsus* Grandi are apparently very convincing. The shape of head, thorax, wings, legs and abdomen in the two genera are very similar. But there are very fundamental differences between the two genera viz. in *Sycophagella agraensis* Joseph the twelve-segmented antenna with a single ring-joint and the unisegmented maxillary and labial palpi alone are sufficient to distinguish the two into separate genera.

In the males of the two genera the similarities are more convincing and marked than in the females—the shape of the head, its division in a transverse plane into two parts (Figs. 16 and 26), the shape and form and number of segments of the antennae, the long thorax with an antero-median longitudinal cleft and lateral notches (Figs. 19 & 27), the shape and nature of the legs with tibial odontoid spines and the abdomen with terminal spiracular processes give them an almost identical constitution. It is in fact very difficult to distinguish the one from the other but for the above-said differences in the nature and shape of the spiracular processes (Fig. 24). It is thus clear that some peculiar factors have brought about the resemblances in the morphological characters of the genera *Sycophaga* and *Sycophagella*, and that these resemblances are more pronounced in the case of the males which spend their embryonal, postembryonal and imaginal lives inside the cavity of the fig. The resemblances are less marked in the female which spends its entire imaginal life outside the fig. There is thus observed a remarkable case of *convergent evolution.* The ecological conditions such as the limited space, humidity, darkness and limited aeration producing peculiar microclimates within the fig may be of value in this connection.

Sycophaga brevitarsus Grandi

1915. *Sycophaga brevitarsus*, Grandi, *Boll. Lab. Zool. Portici,* **10**: 236.
1916. *Sycophaga brevitarsus*, Grandi, *Boll. Lab. Zool. Portici,* **11**: 229.

A comparative study of the morphology of *Sycophaga brevitarsus* Grandi and that of *Sycophagella agraensis* Joseph has shown that (i) the head in the male of *Sycophaga brevitarsus* Grandi is also (as in *Sycophagella agraensis* Joseph divided in a transverse plane into two parts—a smaller antero-dorsal region carrying the antennae and the eyes and a larger postero-ventral region carrying the buccal apparatus (Fig. 26); (ii) the pronotum in the male of *Sycophaga brevitarsus* Grandi is also (as in *Sycophagella agraensis* Joseph) provided with deep lateral notches (Fig. 27). These facts were overlooked by Grandi, and by me.

2. **Neosycoecus,** gen. nov.

Female.—Head distinctly wider between the external margins of the eyes than long. Epistomal margin with a pair of sublateral concavities and a median convex projection ; lateral margin forwards of eyes (gena) distinctly shorter than the longitudinal diameter of the eye; dorsum of head (frons) with a longitudinal shallow groove; eyes large ; ocelli three in an obtuse triangle ;

posterior margin of head weakly concave; antenna with eleven segments, of which the third forms a ring-joint ; mandible bidentate, apical tooth pointed and long, subapical tooth short and blunt ; maxillary palpus four-segmented ; labial palpus two-segmented. Pronotum with a median anterior incurvation; mesonotum with the parapsidal furrows incomplete, being present only in the anterior half of the scuto-scapular region ; scutellum large and overlaps the metanotum ; propodeum divided into a median and two lateral regions, tracheal spiracles with rather small subrotund peritremes. Fore wings two and a half times or more as long as their maximum width, submarginal vein a little less than twice the marginal, stigmal half postmarginal or a little more, costal cell devoid of pubescence, alar cuticle with extremely minute pubescence. Hind wing four times or more as long as wide, with three frenal hooks, alar expanse with extremely minute pubescence. Fore tarsi short, five-segmented, metatarsus about half those of the mid and hind metatarsi ; hind tibiae with odontoid spines; pretarsi of all legs with a pair of curved claws and the enlarged empodium. The eighth abdominal tergite with tracheal spiracles provided with small subrotund peritremes situated laterally; ovipositor long, about three times or more as long as the abdomen. The species with iridescent blue, green and gold colourations.

This genus runs near to couplet No. 2 in Grandi's Key* but is readily separated from the other related known genera in having two ring-joints. Of the three genera viz. *Crossogaster* Mayr, *Seres* Waterst. and *Sycoecus* Waterst. coming under couplet No. 2 of the same key, the genus *Neosycoecus* resembles *Sycoecus* Waterst. alone in possessing a four-segmented maxillary palpus and a two-segmented labial palpus.

Genotype *Neosycoecus indicus*, gen. et sp. nov.

Neosycoecus indicus, sp. nov.

Female.—Length 1.4 mm. Viewed from above iridescent green and gold; ventral side of head and antennal scape yellowish-brown, rest of antenna and ovipositor valves smoky-brown, legs and ovipositor proper melleous, eyes coralline ; wings hyaline, nervures amber.

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* GRANDI, G. *Boll. Lab. Ent. Bologna*, **1** : 80—81 (1928).

Head (Fig. 28) distinctly wider between the external margins of the eyes than long; epistomal margin with a pair of sublateral concavities and a median convexly rounded projection ; dorsum of head (frons) with a longitudinal shallow groove ; lateral margin forwards of eyes (gena) five-sevenths the longitudinal diameter of the eye ; eyes large; ocelli three in an obtuse triangle; postero-median margin of head weakly concave in the median part, rounded off laterally behind the eyes; vertex of head obscurely rugulosely sculptured. Antenna (Fig. 29) with eleven segments, of which the third forms a small ring-joint; scape long, four times as long as thick, thickest in the middle; second segment one and three-fifths as long as thick, with a few setae; fourth segment as long as thick, fifth a little longer than thick; sixth as long as fifth, its length equal to its own thickness ; seventh distinctly thicker than long; eighth as long as seventh but a little thicker than it ; ninth, tenth and eleventh segments fused to form a club with length a little over twice its maximum thickness as measured from the ninth which is thickest of all ; segments four to eleven with long and stout sensoria and long setae as in figure. Maxillary palpus (fig. 28) four-segmented, with the four segments in the proportion 4:6:2:5 beginning from the base ; apical segment with two long setae. Labial palpus (Fig. 28) with two segments of somewhat equal lengths, the apical one slightly thicker than the basal one and with two long setae.

Thorax (Fig. 31) very finely reticulately punctate with a few fine setae. Pronotum with length one-fourth its width, its margins converging anteriorly, with an anterior median incurvation. Mesonotum with the parapsidal furrows incomplete, being present only in the anterior half of the scuto-scapular region ; scutellum rugulose, large and overlaps the metanotum, wider than long and as in figure ; axillae subtriangular, one and one-third as long as wide. Metanotum a narrow transverse area overlapped by the posterior region of the scutellum. Fore wing (Fig. 32) two and three-fifths as long as wide, distal margin rounded off; submarginal vein less than twice the marginal ; postmarginal longer than marginal; stigmal a little longer than half the postmarginal, subclaviform, tilted towards the distal extremity of the wing, with truncated distal extremity and with four rounded sensillae and setae as in figure 33; alar cuticle with extremely minute pubescence, costal cell about ten times as long as wide, bare; marginal fringe short. Hind wing (Fig. 34) with length a little less than six times breadth, alar cuticle with very minute pub-

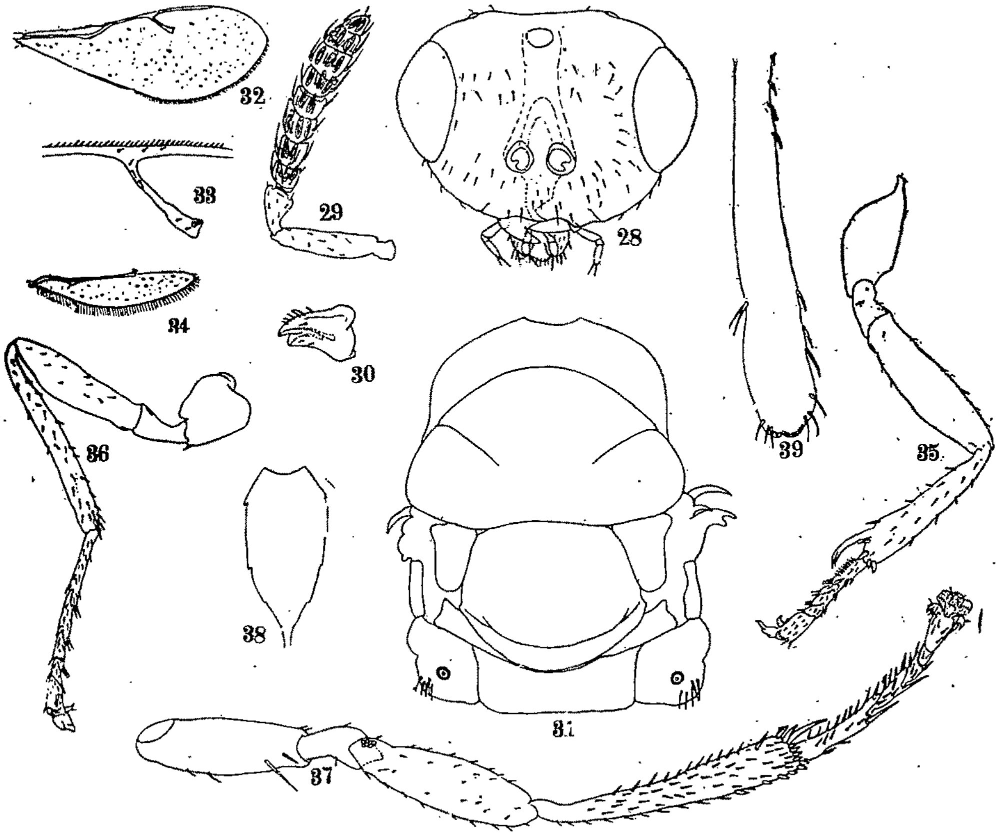

FIG. 28. *Neosycoecus indicus*, gen. et sp. nov., female. Head with mouthparts.
FIG. 29. *Neosycoecus indicus*, gen. et sp. nov., female. Antenna.
FIG. 30. *Neosycoecus indicus*, gen. et sp. nov., female. Mandible.
FIG. 31. *Neosycoecus indicus*, gen. et sp. nov., female. Thorax.
FIG. 32. *Neosycoecus indicus*, gen. et sp. nov., female. Fore wing.
FIG. 33. *Neosycoecus indicus*, gen. et sp. nov., female. Details of stigmal vein.
FIG. 34. *Neosycoecus indicus*, gen. et sp. nov., female. Hind wing.
FIG. 35. *Neosycoecus indicus*, gen. et sp. nov., female. Fore leg.
FIG. 36. *Neosycoecus indicus*, gen. et sp. nov., female. Mid leg.
Fig. 37. *Neosycoecus indicus*, gen. et sp. nov., female. Hindleg.
FIG. 38. *Neosycoecus indicus*, gen. et sp. nov., female. Abdomen.
FIG. 39. *Neosycoecus indicus*, gen. et sp. nov., female. Valve distal part.

escence, three frenal hooks ; marginal fringe rather long. Fore leg (Fig. 35) with coxa a little over twice as long as wide, with a somewhat rounded ventral margin ; trochanter one and a half times as long as wide ; femur about three and a half times as long as wide, widest in the middle, with a few small setae; tibia shorter than the femur, about six times as long as wide, subclaviform with setae and distally with about three odontoid spines and a long forked tibial spur ; tarsi five-segmented, short, armed with setae and spines , metatarsus a little shorter than the two following segments combined and with about eight spines set in a comb-like series as in figure, combined length of the fourth and fifth segments a little less than that of the preceding two segments united and yet a trifle longer than the metatarsus, second, third and fourth segments decreasing in length in order; pretarsus with a pair of small curved claws and the large empodium. Mid leg (Fig. 36) with coxa a little longer than wide ; trochanter about one and a half times as long as wide ; femur four times as long as wide, with a few small setae; tibia long, longer than the femoro-trochanter, with many long setae and spines, tibial spur rather short ; tarsi long, five-segmented, a little less than twice as long as the fore tarsi, armed with setae and spines, metatarsus equal to the second and third segments combined, second, third and fourth segments decreasing in length in order ; pretarsus with a pair of curved claws and the large empodium. Hind leg (Fig. 37) with coxa long, about three times as long as wide, with maximum width in the middle, with short and very long setae as in figure; trochanter twice as long as wide ; femur three and two-thirds as long as wide, elongate-oval, with many setae as in figure ; tibia long, longer than the mid tibia and the hind femur, clearly shorter than the hind femoro-trochanter, subclaviform, with many long spines and setae and with about nine or more odontoid spines in the distal half and a pair of tibial spurs of unequal length as in figure ; tarsi long, about twice as long as the fore tarsi, longer than the mid tarsi, five-segmented, armed with many spines and setae, metatarsus longer than the combined length of the second and the third segments, with a single long ventral spine, fourth and fifth segments united less than the combined length of the second and third segments, second, third and fourth segments decreasing in length in order and with a large spine on each ; pretarsus with a pair of claws and the large empodium. Propodeum about seven times as wide as its median length and divided into a median and two lateral regions ; tracheal spiracles with rather small subrotund peritremes ; setae as in figure.

Abdomen (Fig. 38) long, two and one-fourth times as long as broad ; ovipositor a little less than three times the length of the abdomen ; valves (Fig. 39) with setae, enlarged towards their tip where the setae are larger.

Holotype 1 female dissected on slides Nos. 14b/1-4,14b/1-5, 14b/1-6, 14b/1-7. *Paratypes* females on slides and in spirit.

Geographical Distribution.—Collected by K. J. Joseph from figs of *Ficus infectoria* Roxb. in Hewitt Park, Agra, 31 January, 1952.

BIOLOGICAL NOTES

The insects concerned were found on the tender figs of *Ficus infectoria* Roxb. in Hewitt Park, Agra. For the purpose of study a fresh twig with a few green leaves and some tender figs with female insects on them was removed to the laboratories of the School of Entomology on 5th December, 1951.

1. *Oviposition.*—Preliminary to oviposition the insect takes particular care in selecting a suitable place for the insertion of the ovipositor and deposition of her eggs. With this in view, it wanders over the surface of the fig, feeling the same by means of the tips of its antennae. When it feels a particular spot to be suitable, it stops. Holding on firmly with the aid of its curved claws (with which the legs are provided), the abdomen is raised (Fig. 40) as high as the long posterior legs can raise it, tip of the ovipositor valve is brought in contact with the chosen surface and the insect tries to pierce the same. In this position the anterior part of the body with the head is brought as low as possible in order to facilitate the raising of the abdomen. If the surface is not pierced the site is abandoned while if the effort is successful (Fig. 41) the process is continued. The tip of the ovipositor proper is inserted into the puncture made by the tip of the valve (Fig. 42) and at the same time the ovipositor valve is drawn out. The swollen

tip of the ovipositor valve is, at this stage, found to have folded like a hook (Fig. 43). The antennae and the wings are raised and the insect seems to be under a great strain. The ovipositor is drilled down the wall of the fig by a peculiar action of the abdomen and the hind legs. Very often the ovipositor is seen to be slightly pulled up (possibly since it has taken a wrong course) and then drilled down again. As the ovipositor goes into the fig, the insect creeps back. When the whole of the ovipositor is thrust inside, the abdomen is low and the anterior part of the body together with the head is raised and the hind legs fixed well back beyond the place of insertion of the ovipositor (Fig. 44). The egg is laid at this time.

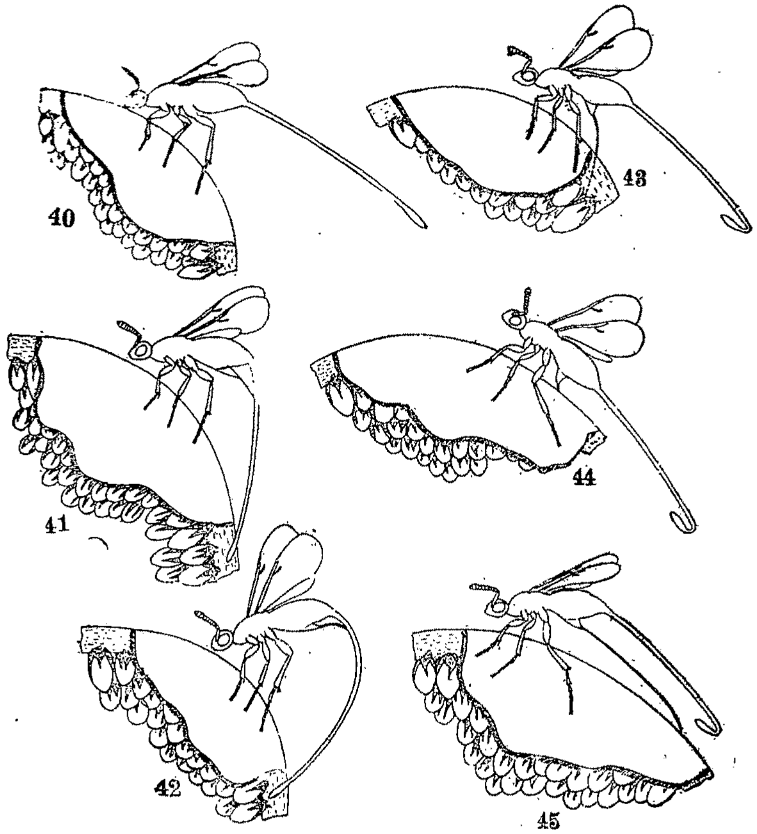

Fig. 40. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage I.
Fig. 41. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage II.
Fig. 42. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage III.
Fig. 43. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage IV.
Fig. 44. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage V.
Fig. 45. *Neosycoecus indicus*, gen. et sp. nov., female. Oviposition, stage VI.

After oviposition, the insect pulls out its ovipositor in a very interesting manner. It slowly raises its abdomen by straightening its bent legs and gently pulls the ovipositor out stage by stage, at the same time slowly creeping forwards till the whole of the ovipositor is out of the fig (Fig. 45). The ovipositor is then concealed away inside the valve, the folded tip of which at this time straightens to assume the normal state.

The whole process of oviposition is found to take about fifteen minutes. Some of the insects actually lay down their lives in the process of egg-laying as in some cases the whole of the egg-laying mechanism gets torn away and detached from the body. A female oviposits several times on the same or on different figs.

2. *Cleaning up.*—The antenna is cleaned by inserting it between the fore tibial spur and the comb-like series of setae on the fore metatarsus and by pulling it out, the process being repeared several times. The wings, abdomen and ovipositor are cleaned by means of the peculiar action of the hind legs. During this process the insect stands firm on its fore and mid legs. In cleaning the ovipositor the insect assumes an almost vertical position with head low, raises the hind legs and sweeps the ovipositor from its very base to the tip.

Neosycoecus longipalpus, sp. nov.

Female.—Length 1.8 mm. Dorsum of head, thorax and abdomen iridescent green, blue and gold; all legs, the ventral sides of head, thorax, abdomen and antennal scape pale brownish-yellow ; rest of antenna pale smoky-brown ; wings hyaline, nervures amber ; ovipositor valves dark brown ; eyes fuscous.

Head.—(Fig. 46) distinctly wider between the external margins of the eyes than long; epistomal margin (Fig. 47) presents a pair of large sublateral concavities and a clearly convex median projection; lateral margin forwards of eyes a little less than half the longitudinal diameter of the eye ; postero-lateral margin of head behind the eyes rounded ; postero-median margin weakly concave; eyes large ; ocelli large, three in an obtuse triangle; dorsum of head (frons) with a broad shallow groove starting from the place of insertion of the antennae and reaching up to the anterior median ocellus. Head obscurely rugulosely punctate. Antenna (Fig. 48) with eleven segments of which the third forms a ring-joint ; scape a little less than four and a half times as long as thick, with a few short setae ; scond segment a little less than one and a half times as long as its maximum distal thickness, with a few setae ; third segment forms the ring-joint ; fourth a little longer than thick;

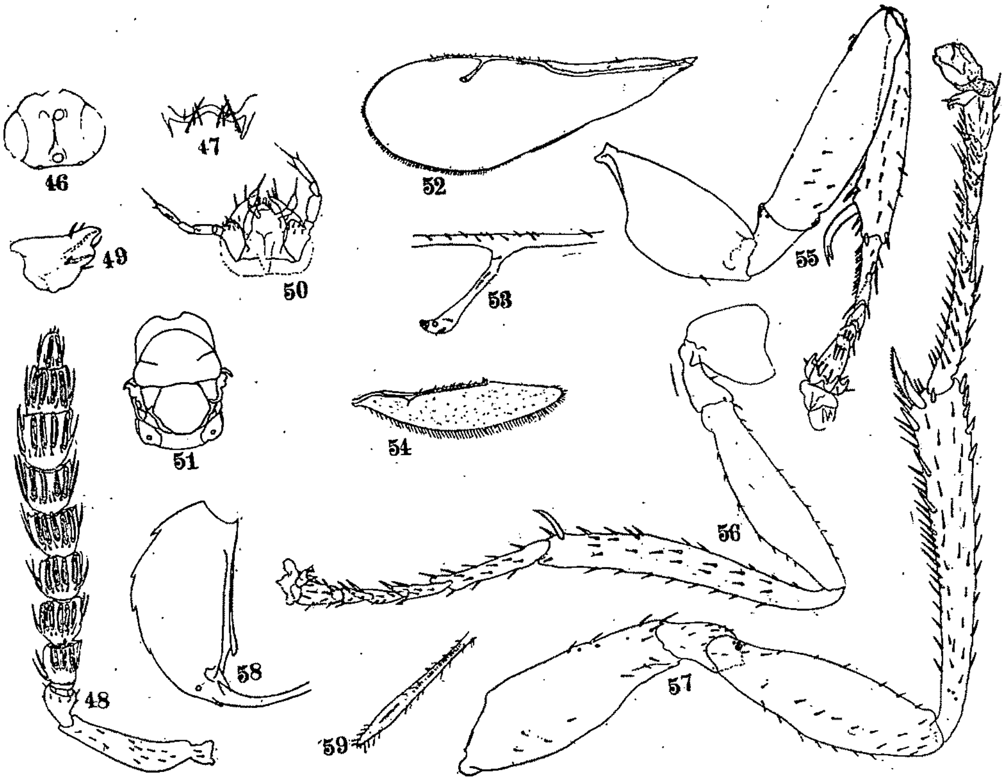

FIG. 46. *Neosycoecus longipalpus*, sp. nov., female. Head.
FIG. 47. *Neosycoecus longipalpus*, sp. nov., female. Epistomal margin.
FIG. 48. *Neosycoecus longipalpus*, sp. nov., female. Antenna.
FIG. 49. *Neosycoecus longipalpus*, sp. nov., female. Mandible.
FIG. 50. *Neosycoecus longipalpus*, sp. nov., female. Maxillae and labium.
FIG. 51. *Neosycoecus longipalpus*, sp. nov., female. Thorax.
FIG. 52. *Neosycoecus longipalpus*, sp. nov., female. Fore wing.
FIG. 53. *Neosycoecus longipalpus*, sp. nov., female. Details of stigmal vein.
FIG. 54. *Neosycoecus longipalpus*, sp. nov., female. Hind wing.
FIG. 55. *Neosycoecus longipalpus*, sp. nov., female. Fore leg.
FIG. 56. *Neosycoecus longipalpus*, sp. nov., female. Mid leg.
FIG. 57. *Neosycoecus longipalpus*, sp. nov., female. Hind leg.
FIG. 58. *Neosycoecus longipalpus*, sp. nov., female. Abdomen.
FIG. 59. *Neosycoecus longipalpus*, sp. nov., female. Valve, distal part.

fifth equal to fourth ; sixth as long as fifth but a little less thick; seventh smaller than fifth, a little longer than thick ; eighth equal to seventh ; ninth, tenth and eleventh segments fused to form a long club a little less than thrice as long as its maximum thickness ; segments four to eleven with long setae and with a whorl of long sensoria on each. Mandible (Fig. 49) subtriangular, a little less than one and a half times as long as broad, bidentate, apical tooth long and acute, subapical tooth blunt, with setae as in figure. Maxillary palpus (Fig. 50) four-segmented with the segments beginning from the base in the ratio 4:7.5:5:9, the terminal segment with a short seta subapically and a long seta apically. Labial palpus (Fig. 50) two-segmented, the segments beginning from the base in the ratio 5.5:5, the terminal segment with a very short seta subapically and a long seta apically.

Thorax (Fig. 51). Width of pronotum a little less than thrice its maximum length, lateral margins converging anteriorly, with an anterior median incurvation. Mesonotum reticulately punctate, with the parapsidal furrows incomplete, being present only in the anterior half of the scuto-scapular region ; scutellum finely rugulose, large, as long as wide, its posterior region overlaps the metanotum ; axillae subtriangular, longer than wide ; metanotum a narrow transverse area overlapped by the posterior extension of the scutellum. Fore wing (Fig. 52) with length two and a half times its maximum breadth, costal cell ten times as long as wide, bare; submarginal vein a little less than twice the marginal; postmarginal a little longer than marginal ; stigmal half postmarginal, subclaviform, tilted towards the distal extremity of the wing with a pointed distal extremity bearing four sensillae and setae as in figure 53 ; alar cuticle with extremely minute pubescence, distal extremity rounded ; marginal fringe short. Hind wing (Fig. 54) four and a half times as long as wide, with three frenal hooks, alar cuticle with extremely minute pubescence, distal extremity roundedly pointed; marginal fringe rather long. Fore leg (Fig. 55) with coxa a little more than twice as long as wide, with very few short setae; trochanter distinct, a little over one and a half times as long as wide; femur a little longer than four times its width, with a few short setae ; tibia subclaviform, six times as long as wide, shorter than the femur, with setae, two odontoid spines and a long bifid spur as in figure ; tarsi short, five-segmented, armed with setae and spines, metatarsus a trifle less than the two following segments combined and with a row of about nine setae arranged in a comb-like series as in figure, combined length of fourth and fifth segments equal to that of the two preceding segments; second, third and fourth segments decreasing in length in order; pretarsus with a pair of falciform claws and the large empodium. Mid leg (Fig. 56) with coxa subtriangular, a little longer than wide; trochanter a little less than twice as long as wide; femur about four times as long as its maximum width, with a few short setae ; tibia about nine times as long as its maximum width, longer than the femoro-trochanter, subclaviform, with setae of different sizes and a large tibial spur; tarsi long, five-segmented, one and three-fourths as long as the tibia, armed with setae and spines, matatarsus definitely longer than the two following segments combined, second, third and fourth segments decreasing in length in order; pretarsus with a pair of falciform claws and the large empodium. Hind leg (Fig. 57) with coxa long, two and two-thirds as long as wide, with setae of various sizes as in figure; trochanter a little over twice as long as wide, with small setae; femur elongate-oval, about three and one sixth as long as wide, with many setae; tibia long, subclaviform, six and a half times as long as wide, longer than the femoro-trochanter, with numerous long setae, about ten odontoid spines and a pair of tibial spurs of unequal lengths as in figure ; tarsi long, five-segmented, armed with setae and spines, metatarsus half as long as all the five tarsal segments combined, second, third and fourth segments decreasing in length in order ; pretarsus with a pair of falciform claws and the large empodium. Propodeum about six times as wide as its median length ; divided into a median and two lateral regions, with tracheal spiracles provided with rather small subrotund peritremes and with setae as in figure 51.

Abdomen (Fig. 58). Long, a little less than twice as long as broad, eighth tergite with a pair of tracheal spiracles furnished with small subrotund peritremes ; ovipositor a little less than four times as long as the abdomen, swollen at the terminal portion as in figure 59.

Holotype 1 female dissected on slides Nos. 3b/3-2, 3b/3-3. *Paratypes* 1 female on slide No. 3b/3-1 and 13 females in spirit.

Geographical distribution.—Collected by K. J. Joseph from figs of *Ficus asperrima* Roxb. on way to Vazhapara Beat, Pathanapuram Taluk, Travancore, dated 26-V-1951.

This species differs from the genotype *Neosycoecus indicus*, Joseph in the possession of the following important characters: (i) maxillary palpus very long; (ii) scutellum as wide as long; (iii) fore wing two and a half times as long as wide; (iv) stigmal vein half the postmarginal and pointed at its distal extremity; (v) abdomen a little less than twice as long as broad; ovipositor a little less than four times as long as the abdomen.

3. **Indothymus,** gen. nov.

Female.—Head distinctly wider between the external margins of the eyes than long ; epistomal margin with a pair of large sublateral concavities and a median angulate process; lateral margin (gena) forwards of eyes shorter than the longitudinal diameter of the eye ; dorsum of head (frons) with a longitudinal shallow groove ; eyes large ; ocelli three in an obtuse triangle ; posterior margin of head weakly concave ; antenna with twelve segments, of which two (the third and the fourth) form ring-joints; mandible long, about one and a half times as long as wide, bidentate, apical tooth long and pointed, subapical tooth short and blunt ; maxillary palpus three-segmented ; labial palpus two-segmented. Mesonotum with parapsidal furrows incomplete, being present only in the anterior half of the scuto-scapular region; scutellum large and overlaps the metanotum ; propodeum divided into a median and two lateral regions, tracheal spiracles with rather small subrotund peritremes. Fore wings about two and a half times as long as its maximum breadth; submarginal vein a little less than one and a half times as long as the marginal ; postmarginal equal to twice or a little less than twice the stigmal ; stigmal characteristically tilted, the proximal part towards the distal margin of the wing, with a distinct beak-like prolongation bearing three or four small rounded sensillae, the distal portion enlarged and thumb-like and slightly turned towards the wing base ; costal cell bare ; alar cuticle bears 9-15 characteristic brownish-black hairs in the triangular area enclosed by the marginal and stigmal veins and an imaginary line drawn from the apex of the stigmal vein to the base of the marginal vein ; rest of the alar cuticle with microscopically minute pubescence ; marginal fringe long. Hind wing three and a half to slightly over five times as long as wide ; marginal fringe long ; with three frenal hooks ; alar cuticle with microscopically minute pubescence. Fore tarsi short, five-segmented; hind tibiae with odontoid spines along its outer margin ; pretarsi of all legs with a pair of small claws and moderately large empodium. Abdomen long, ovipositor four to five times as long as the abdomen, tip of ovipositor valves remarkably swollen. The species with iridescent green hues.

This genus runs up to couplet No. 2 in Grandi's Key*. It differs from *Lipothymus* Grandi in several characters, the most important of which is the possession of three-segmented maxillary palpus.

Genotype *Indothymus infectorius*, gen. et sp. nov.

Indothymus infectorius, sp. nov.

Female.—Length 1.27 mm. Viewed dorsally iridescent green ; legs melleous ; scape and funicle of antenna yellowish-brown, rest of antenna dark brownish-yellow ; eyes pale pinkish-red ; wings hyaline, nervures amber.

Head (Fig. 60) distinctly wider between the external margins of the eyes than long ; epistomal margin (Fig. 61) with a pair of large sublateral concavities and a median angulate process ; lateral margins of head forwards of eyes a little shorter than the longitudinal diameter of the eye ; dorsum of head with a median longitudinal shallow groove ; eyes large ; ocelli three in an obtuse triangle ; postero-median margin of head behind the eyes weakly concave, postero-lateral margin of head behind the eyes rounded off ; head irregularly closely and minutely punctate, with a few very small setae. Antenna (Fig. 62) with twelve segments, of which two (the third and the fourth) form ring-joints ; scape four times as long as thick with maximum thickness at the

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*GRANDI, G. *Boll. Lab. Ent. Bologna*, **1** : 80-81 (1928).

base, gently narrowing towards apex, about equal in length to the five following segments combined; second segment about two-fifths the scape and a little less than one and a half times as long as its maximum thickness, with a few setae ; fourth segment a little larger than third ; segment five a little thicker than long ; sixth lightly larger than fifth, a little longer than its own thickness ; seventh as long as thick, smaller than sixth but larger than fifth ; eighth as long as seventh but a little thicker ; ninth as long as eighth but slightly thicker than it ; tenth, eleventh and twelfth segments fused to form a club with length equal to a little over twice the thickness of the tenth segment which is thickest of all the twelve segments ; segments five to twelve with whorls of long sensoria and setae. Mandible (Fig. 61) one and a half times as long as thick, with an anteriorly prolonged basal part ; apical tooth curved and pointed, subapical tooth shorter and blunt. Maxillary palpus (Fig. 63) with three segments, of which the apical one is longest and bears at its tip four long setae ; labial palpus (Fig. 63) with two segments, the apical one smaller than the basal one and with two small setae.

Thorax (Fig. 64). Pronotum wider than long, converging anteriorly. Mesonotum closely irregularly and minutely punctate with the punctae distinctly separated from each other by a distance at least equal to their diameter, with parapsidal furrows incomplete, being present only in the anterior half of the scuto-scapular region; scutellum large, with punctation as in mesonotum, a little wider than long, its posterior region overlapping the metanotum ; axillae subtriangular, longer than wide. Metanotum a narrow transverse area overlapped in its median region by the posterior part of the scutellum. Propodeum divided into a median and two lateral regions ; tracheal spiracles with subrotund peritremes ; setae as in figure. Fore wing (Fig. 65) about two and a half times as long as its maximum breadth, rounded off at the distal extremity ; costal cell about nine times as long as its maximum width, bare ; submarginal vein a little less than one and a half times as long as the marginal ; postmarginal about equal to twice the stigmal ; stigmal vein thumb-like, (Fig. 66) characteristically tilted, the proximal part towards the distal margin of the wing with a distinct beak-like prolongation bearing four small sensillae, the distal part enlarged and slightly tilted towards the wing base ; alar cuticle with about fifteen characteristic brownish-black hairs in the triangular area enclosed by the marginal and stigmal veins and an imaginary line drawn from the apex of the stigmal vein to the base of the marginal vein ; rest of alar cuticle with microscopically minute pubescence ; marginal fringe long. Hind wing (Fig. 67) over five times as long as its maximum breadth ; marginal fringe long ; with three frenal hooks ; alar cuticle with microscopically minute pubescence. Fore leg (Fig. 68) with coxa over twice as long as wide, with a few setae ; trochanter one and a half times as long as wide ; femur a little less than four times as long as wide, with a few setae ; tibia shorter than femur, subclaviform, over four times as long as wide, with about two spines, three odontoid

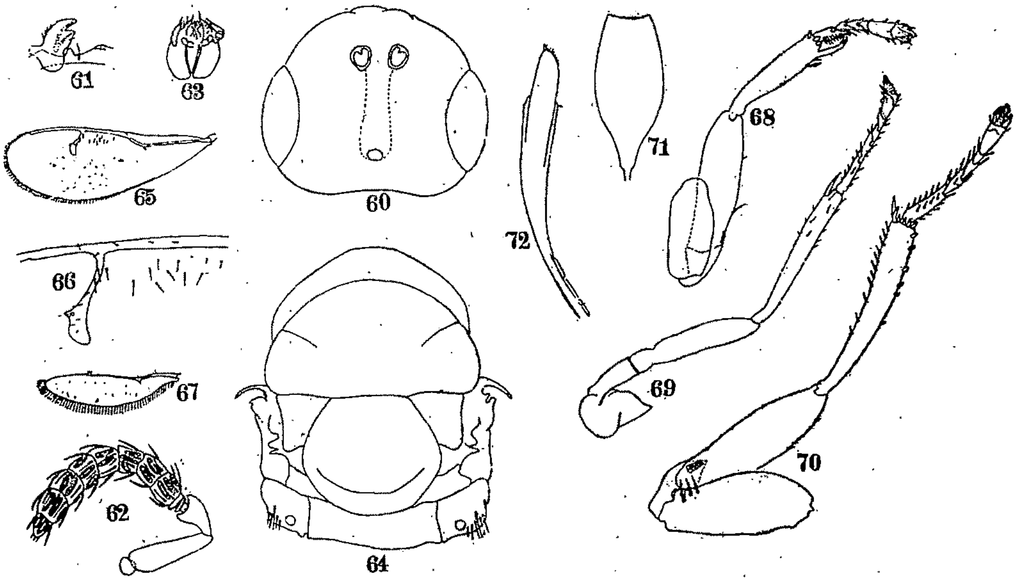

Fig. 60. *Indothymus infectorius*, gen. et sp. nov., female. Head.
Fig. 61. *Indothymus infectorius*, gen. et sp. nov., female. Epistomal margin and mandible.
Fig. 62. *Indothymus infectorius*, gen. et sp. nov., female. Antenna.
Fig. 63. *Indothymus infectorius*, gen. et sp. nov., female. Maxillae and labium.
Fig. 64. *Indothymus infectorius*, gen. et sp. nov., female. Thorax.
Fig. 65. *Indothymus infectorius*, gen. et sp. nov., female. Fore wing.
Fig. 66. *Indothymus infectorius*, gen. et sp. nov., female. Details of stigmal vein.
Fig. 67. *Indothymus infectorius*, gen. et sp. nov., female. Hind wing.
Fig. 68. *Indothymus infectorius*, gen. et sp. nov., female. Fore leg.
Fig. 69. *Indothymus infectorius*, gen. et sp. nov., female. Mid leg.
Fig. 70. *Indothymus infectorius*, gen. et sp. nov., female. Hind leg.
Fig. 71. *Indothymus infectorius*, gen. et sp. nov., female. Abdomen.
Fig. 72. *Indothymus infectorius*, gen. et sp. nov., female. Valve, distal part.

spines and a long bifid tibial spur ; tarsi five-segmented, armed with setae, metatarsus about equal to the two following segments combined and with a row of setae set in a comb-like series as in figure ; pretarsus with a pair of small claws and moderately large empodium. Mid leg (Fig. 69) with coxa a little wider than long; trochanter long, twice as long as wide ; femur about four and a half times as long as wide, with a distinctly constricted part proximally ; tibia a little less than nine times as long as wide, subclaviform, equal to the femoro-trochanter, with long setae and with a long tibial spur ; tarsi five-segmented, armed with setae and spines, metatarsus equal to the two following segments combined ; pretarsus with a pair of small claws and the moderately large empodium. Hind leg (Fig. 70) with coxa about two and a half times as long as wide, widest in the middle, with three or four long setae as in figure ; trochanter about twice as long as wide ; femur over three times as long as wide, elongate-oval, with a few setae ; tibia six times as long as wide, subclaviform, a little longer than the femero-trochanter, with six odontoid spines along its outer margin, long spines and setae on its inner margin, and with five long spines and a pair of tibial spurs of unequal lengths at the extreme distal margin ; tarsi five-segmented, armed with many spines and setae, metatarsus longer than the three following segments combined; pretarsus with a pair of small claws and the moderately large empodium.

Abdomen (Fig. 71). Long, about two and two-thirds as long as broad ; ovipositor five times as long as the abdomen, ovipositor valves distinctly swollen (Fig. 72) at the tip.

Holotype 1 female dissected on slides Nos. 14-7/1, 14-7/2. *Paratypes* 2 females in spirit.

Geographical distribution.—Collected by K. J. Joseph, from figs of *Ficus infectoria* Roxb. in P. A. C. grounds, Agra, dated 26th September, 1950.

Indothymus crenulatus, sp. nov.

Female.—Length 1.66 mm. Iridescent green with a fundamental brownish-yellow colour ; legs pale yellow except for the hind coxa which, together with the antennae, are sooty-brown ; wings hyaline, nervures amber.

Head (Fig 73) a little less than one and a half times as wide between the external margins of the eyes than long ; epistomal margin with a well-developed distally rounded process, lateral margin forwards of eyes four-fifths the longitudinal diameter of the eye ; dorsum of head with a median longitudinal shallow groove ; eyes large ; ocelli three in an obtuse triangle ; postero-median margin of head weakly concave ; postero-lateral margins behind the eyes rounded off ; head finely closely and minutely punctate. Antenna (Fig. 74) with twelve segments of which the third and the fourth form ring-joints ; tenth, eleventh and twelfth segments fused to form a club ; scape as in figure, widest basally, a little less than four times as long as its maximum width, as long as the five following segments united, with a few setae ; second segment two-fifths the scape and a little longer than one and a half times its own width, with a few setae ; third and fourth segments somewhat equal ; fifth segment as long as thick ; sixth equal in length to fifth but a little more thick ; seventh and eighth segments of the same size, their length being equal to that of the fifth but a little less thick ; ninth a little shorter than eighth, thicker than long ; tenth and eleventh segments equal, thicker than long ; twelfth subconical, as long as its own maximum basal thickness, club about two and a half times as long as its maximum thickness ; segments five to twelve furnished with long sensoria and setae as in figure. Mandible (Fig. 75) long, about one and a half times as long as broad ; bidentate, with long and acute apical tooth and stout, blunt and shorter subapical tooth, with a few setae. Maxillary palpus (Fig. 76) three-segmented, third segment longest, with a very long seta and one or two short setae apically ; second segment short and stout ; first narrow basally, widening towards apex ; the lengths of the three segments in the ratio 2.5 : 2.5 : 5. Labial palpus (fig. 77) two-segmented, the two segments somewhat equal in length.

Thorax (Fig. 78). Pronotum markedly wider than long, its lateral margins converging forwards. Mesonotum with well separated regular minute punctae ; parapsidal furrows incomplete, being indicated only in the anterior half of the scuto-scapular region ; scutellum very finely longitudinally rugulosely striate, wider than long, narrow anteriorly, widening posteriorly, its posterior region overlaps the metanotum ; axillae subtriangular, a little longer than wide. Metanotum a narrow transverse area overlapped in its median part by the posterior region of the scutellum. Propodeum divided into a median and two lateral parts, with setae and tracheal spiracles provided with subrotund peritremes as in figure. Fore wings (Fig. 79) with costal cell about eight times as long as broad ; submarginal vein one and three-

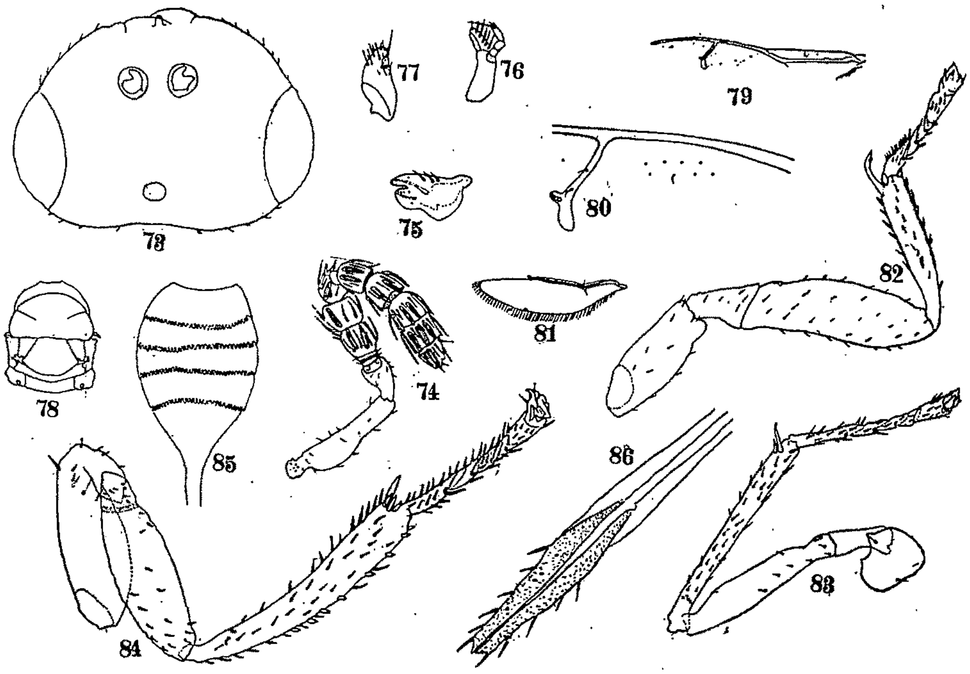

Fig. 73. *Indothymus crenulatus*, sp. nov., female. Head.
Fig. 74. *Indothymus crenulatus*, sp. nov., female. Antenna.
Fig. 75. *Indothymus crenulatus*, sp. nov., female. Mandible.
Fig. 76. *Indothymus crenulatus*, sp. nov., female. Maxilla.
Fig. 77. *Indothymus crenulatus*, sp. nov., female. Part of labium with labial palpus.
Fig. 78. *Indothymus crenulatus*, sp. nov., female. Thorax.
Fig. 79. *Indothymus crenulatus*, sp. nov., female. Fore wing.
Fig. 80. *Indothymus crenulatus*, sp. nov., female. Details of stigmal vein.
Fig. 81. *Indothymus crenulatus*, sp. nov., female. Hind wing.
Fig. 82. *Indothymus crenulatus*, sp. nov., female. Fore leg.
Fig. 83. *Indothymus crenulatus*, sp. nov., female. Mid leg.
Fig. 84. *Indothymus crenulatus*, sp. nov., female. Hind leg.
Fig. 85. *Indothymus crenulatus*, sp. nov., female. Abdomen.
Fig. 86. *Indothymus crenulatus*, sp. nov., female. Valve, distal part.

sevenths as long as the marginal ; marginal equal to four-fifths the postmarginal, postmarginal a little more than twice the stigmal; stigmal vein (Fig. 80) thumb-like, characteristically tilted, the proximal part towards the distal margin of the wing with a distinct beak-like projection bearing four small sensillae, the distal part of the stigmal vein enlarged and slightly tilted towards the wing base ; alar cuticle with about a dozen characteristic brownish-black hairs in the triangular area enclosed by the marginal and the stigmal veins and an imaginary line drawn from the apex of the stigmal vein to the base of the marginal vein ; rest of alar cuticle with microscopically minute pubescence ; marginal fringe long. Hind wing (Fig. 81) about three and a half times as long as broad, alar cuticle almost bare, with three frenal hooks ; marginal fringe moderately long. Fore leg (Fig. 82) with coxa two and one-third as long as wide, with a few setae ; trochanter over one and a half times as long as wide ; femur over five times as long as its own width, with setae as in figure ; tibia markedly shorter than femur, subclaviform, with setae, a long bifid apical spur and odontoid spines at the distal margin as in figure ; tarsi five-segmented, much shorter than the tibia, armed with setae, metatarsus shorter than the two following segments combined and with about ten setae set in a comb-like series as in figure; pretarsus with a pair of curved claws and the large empodium. Mid leg (Fig. 83) with coxa a little wider than long ; trochanter over twice as long as wide ; femur about five times as long as its maximum width, with a marked constriction near its base and with a few setae ; tibia long, longer than the femur, subclaviform, about eleven times as long as its maximum width, equal to the femoro-trochanter, with setae and an apical spur as in figure ; tarsi five-segmented, markedly shorter than the tibia, armed with setae, metatarsus a little longer than the two following segments combined ; pretarsus with a pair of small claws and the large empodium. Hind leg (Fig. 84) with coxa about two and three-fourths as long as wide , widest in the middle, with three very long setae on its ventral distal region besides other small setae as in figure ; trochanter a little more than twice as long as wide ; femur elongate-elliptic, with a definite constriction proximally where the cuticle is faintly chitinised and hence almost transparent, a little longer than the coxa, over twice as long as its maximum width, with setae as in figure;

tibia very long, subclaviform, recurved, seven times as long as its maximum width, distinctly longer than the femoro-trochanter, with setae, the inner margin with about nine spines and the outer margin with about eight short odontoid spines, the distal extremity with two spurs of unequal lengths and two to three spines ; tarsi equal in length to the mid tarsi, five-segmented, armed with setae and spines, metatarsus shorter than the three following segments combined ; pretarsus with a pair of curved claws and the large chitinised empodium.

Abdomen (Fig. 85). Long, one and two-thirds as long as broad, with the distal margins of the tergites crenulate ; ovipositor very long, four times as long as the abdomen, distally swollen (Fig. 86) and with a few setae.

Holotype 1 female and parts of a second female dissected on slides Nos. 7 & 8/5-1, 7&8/5-2, 7&8/5-3.

Geographical distribution.—Collected by K. J. Joseph from figs of *Ficus bengalensis* Linn. from Botanical Gardens, Trivandrum, dated 25th May and 15th June, 1950.

This species differs from the genotype *Indothymus infectorius* Josheph in possessing the following important characters :— (i) postmarginal a little more than twice the stigmal ; alar cuticle with about a dozen characteristic brownish-black hairs ; (ii) fore femur over five times as long as its own thickness ; fore metatarsus shorter than the two following segments combined ; mid metatarsus a little longer than the two following segments combined ; hind tibia distinctly longer than the femoro-trochanter, with about eight odontoid spines along its outer margin ; hind metatarsus shorter than the three following segments combined; (iii) abdomen one and two-thirds as long as broad ; distal margins of the abdominal tergites crenulate ; ovipositor four times as long as the abdomen.

ORGANIC EVOLUTION*

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This paper examines our ideas on organic evolution from an entirely new angle—against a background, of which the basic concept is "the organism is a whole"—in Whitehead's (78,79,80) terminology a *nexus* of integrated units. While the concept itself is certainly not new, we appear to have so far ignored it in our discussions on evolution. In the course of my twenty-five years' work on neosplastic growths, primarily in plants and to a certain extent in animals, I have recognized the far-reaching significance of this principle. It is possible, in the light of this concept, to understand much that is at present obscure in various problems connected with organic evolution. It should be stated at the outset that the studies on neoplasia were not however undertaken with a view to uphold any particular theory of evolution and no direct reference is made here to them.

1. Conflict Of Ideologies

Despite popular belief that evolution was satisfactorily "explained" by Darwin, the conflict and bitterness that divide biologists today into two ideologically opposing camps, testify largely to our general ignorance. The conflict arises partly from the mutual ignorance of workers in different fields and partly from the enormous advances in certain narrowly specialized branches like cytology and genetics.

According to the orthodox biologists, "variations", which are the raw materials of evolution, are due to causeless, spontaneous, random changes in the genes and chromosomes of the germ cells—*mutations*—and are not *all* primarily related to the needs of the organism and are not certainly caused by changes in the environmental conditions. If some of the mutations have any bearing to the environmental needs, it is merely due to accident. In the words of White (77) mutations are "physico-chemical accidents, which are *non-adaptive* in origin. Natural selection acts as a filter which eliminates mutations and rearrangements which are disadvantageous and favours those which are advantageous. The number of mutations and rearrangements which become incorporated in phylogeny is only a small fraction of the total number which occur, the *majority being disadvantageous*." Since according to these views all heritable changes are only due to mutations and since mutations are spontaneous, evolution is not directly adaptive. Adaptations are mere accidents, depending upon the change being not ill-fitting.

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The brilliant researches of Johannsen, Wilson, Caspersson, Darlington, Mather, Morgan, Sonneborn, Brachet and numerous others, following the rediscovery of Mendel by Correns, during the past half a century, located the genes, revealed its chemical composition and seemed to explain nearly every phenomena of heredity and its "variations." The admittedly enormous aptitude of the gene theory for describing the results of breeding experiments and even for predicting the future behaviour of organisms in development and heredity, has so greatly impressed several biologists that they have nearly forgotten the extreme shakiness of the foundations on which these ideas have been built. There is no denying the fact that changes, both quantitative and qualitative, occur in the nuclear material during meiosis. The proof provided by the geneticists themselves that mutations are the result of irregularities in meiosis due to germ weakening, does not however seem to have weakened their conviction. It has also been asserted (49) that chromosomes are not permanent structures in a cell but are merely transitory in nature, formed at each division and disappearing afterwards. The position effects, the apparent over-lapping of the genes and various other difficulties that recently led Goldschmidt (25) to abandon the concept of particulate unit character of the genes have not also materially altered the situation. Even the recent demonstration that inheritance is not all nuclear (Mendelian) but cytoplasmic hereditary particles also exist and act as partners of the nuclear genes, has equally failed to re-orientate our ideas. Weismann's (75) germplasm is still the sole carrier of heredity: it builds and controls the soma, but is itself unaffected by it. Thus has been kept alive the wholly unsatisfactory and extremely anthropocentric theory of origin of species through natural selection, with which Darwin himself was not wholly satisfied. It is hardly worth referring here to the now-all-too-familiar arguments for and against the mutation theory, which have in any case only a historical value.

A great many biologists have however never really wholly reconciled themselves to this idealistic concept of causeless, *purposeless* evolution. While not rejecting the genetic basis, they have refused to believe that the variations are due to random, causeless changes in genes and chromosomes. Variations arise directly under the influence of environmental changes and are directed to the changing needs of the organism. Changes in the environment of the organisms bring about changes in their needs and changes in needs necessarily bring about parallel changes in habits. Changes in habits involve use or disuse of parts, thus leading on to their modification. *Function precedes, determines and controls structure.* Mutations are therefore not the only heritable changes, but also the changes by which an organism becomes better suited functionally and structurally to changing environment—*adaptation.* The accumulation of such adaptations constitutes descent with change and evolution is therefore adaptative. *Evolution in its entirety is an expression of continuous adaptation* : it is in a sense "purposive." Adaptations are not mere accidents and do not arise as a by-product of the elimination of misfits and unfits.

These views have however nearly always been under a sort of stigma, having been severely ridiculed by Weismann (75), particularly because of the supposed absurdity of inheritance of the so-called acquired characters, the changes that changing conditions of the environment bring about in the body of an individual independent of the germ constitution. Are not twenty-two generations of mice (making up a total of 1592 rodent martyrs to the advancement of human knowledge !) mutilated by Weismann enough to settle the matter once and for all ? Use and disuse and changes in habit involve only the soma ; environment doubtless influences the soma, which however perishes, at least in the higher multicellular animals. Since the germ alone is the sole carrier of heredity and since it alone survives and gives rise to a new generation of soma, there is *no apparent way* in which somatic changes can be inherited. Unless such changes can be shown to be heritable, they are of no evolutionary significance.

That heredity should be controlled by such a special hereditary substance that builds the soma, remains in that soma for a whole life-time, is nourished by the very self-same soma and indeed builds itself up out of that same somatic material, controls the soma in all its functions and activities and yet is itself not affected by it seems rather very strange. It is at complete variance with the results of recent progress in many fields of biology. To assume such a special immortal hereditary substance involves the ridiculous idea that within the functional and metabolic *unity* of an organism, there exists something which controls metabolism but itself not subject to metabolism. Metabolism is life and leads on to self propagation ; self propagation in turn involves heredity, which must therefore be the property of life.

The problem is rather complicated by genes, polygenes, supergenes, genes that intensify or suppress other genes, genes that control the mutation of other genes, plasmagenes, precursors, RNA, DNA, chromosomes, crossing-over, linkage, mutations, variations, Dauermodifikation, germ, soma, environment, etc., which are all real—perhaps a little *too* real. We seem literally to have been concentrating ourselves on the individual leaves and losing sight of the forest ; in a sense we are lost like the proverbial babes in the woods of our own creation. Orthodox biologists cannot but recognize the influence of environment and value adaptations greatly ; they refer to it daily. They are doubtless aware that it is often difficult to say precisely where the organism ends and where the environment begins. An organism is an integral part of the environment in which it exists ; the organism *and the environment constitute an intimately and mutually interacting and adjusting dynamic system.* Environment is changing, but not with reference to the needs of the organism. It is for the organism to fit itself to the changing conditions of environment and it is inconsistent to deny the direct role of environment in moulding the organism. On the other side, even Lysenko (44,45) has not belittled the importance of genes and chromosomes.

We appear therefore to have reached a complete deadlock. Some facts point in one direction and others in the opposite direction. Field workers, bacteriologists, palaeontologists and Russian biologists present us with facts which are difficult to explain except by admitting that the influences of environment on soma are inherited. On the other hand laboratory workers, mostly cytologists and geneticists, deny this possibility, because *they can see no mechanism.* The fact that we cannot explain how a thing arises is however no proof that it does not arise. The real crux of the difficulty then lies in the problem of inheritance of the so-called acquired characters.

2. INHERITANCE OF "ACQUIRED CHARACTERS"

The evidence that the biologists have sought for the inheritance of somatic changes arising independently of the genetic changes, under the influences of the changes in environmental conditions, has however been there all the time : Nature herself seems to have carried out all the crucial experiments and indeed even neatly tabulated the results. We seem however to have been particularly stupid in ignoring them so long. Recent progress in biology has not only completely failed to substantiate Weismann, but has actually strengthened his opponents.

Experimental and observational evidence from a great many fields, dealing with plants and animals, both low and high in evolutionary scale, collected together and summarized recently by Martin (50), afford us important clues. We now have incontrovertible evidence, which establishes beyond all reasonable doubt that heredity does not primarily concern visible characters like colour, hairiness, tallness, etc., with which every student of mendelism is familiar. These characters are outward expressions of complex inner and invisible changes. The inheritance of such visible characters is preceded by the inheritance of capacity of the organism to produce visible characters. This capacity arises from the reaction of the organism to changes in the conditions of life. The environmental changes are the stimuli to which the organism responds and by so responding becomes attuned to them. As any student of physiology and immunology should be aware, this attunement manifests itself in brisker and quicker response if the stimulus is repeated within the life-time of the individual. The attunement enables the organism to respond more easily if the altered conditions of environment persist. Although any structural modifications that arise in association with the reaction may disappear sooner or later, the attunement persists much longer than either the stimulus or the modifications in structure and disappears only very gradually. Immunity acquired by an individual as a result of the attack of a disease is generally temporary and diminishes with the passage of time. We know however that a second attack of the same disease is very much milder than the first. The first attack has evidently left the individual better prepared to react to a second one. The effect of the first attack on the individual is one that facilitates reaction. Topley & Wilson (72) have shown for example that even after the complete disappearance of clinical demonstration of antibodies, the tissues are left in a state of increased reactivity, so that they respond more briskly to any subsequent stimulus of the same pathogen. This is fully corroborated by the fact that the larger the dose of vaccine and the more often it is given, the more lasting the immunity. With passage of time the cells like the reticulo-endothelial system and lymphocytes that originally produced the antigen are themselves replaced by their progeny in the body. The antibodies have also passed out and yet the individual reacts to the second attack even after several years more promptly and with more efficiency than on the first occasion. This is clear proof that the reticulo-endothelial cells that originally produced the antibody have transmitted to their progeny their capacity or attunement to produce the same when needed. Furthermore, we have evidence of the inheritance of acquired immunity and susceptibility to diseases from numerous experiments and observations (Metalinkov, 51)*. Webster's experiments fully establish the inheritance of the susceptibility to mouse typhoid. Such inheritance of acquired immunity to specific antibody has been demonstrated by Sonneborn (65) in *Paramecium*. Attention may also be drawn to the interesting results of Henslow (32), who grew *Ononis spinosa* on moist soil and in humid atmosphere, using the seeds gathered from plants growing in very dry conditions and possessing conspicuous spines. The spines of the plants in the first generation growing under humid conditions were very much reduced. The seeds from these plants were used to raise a second generation under moist conditions. In these plants the spines were entirely absent and the plants themselves could hardly be distinguished from another species *Ononis repens*. Brief references may also be made to the well known works of Durken and Kammerer. In Durken's (19) experiments with the larvae of *Pieris brassicae* we can recognize the inheritance of the attunement to the stimulus, so that the response of the second generation is very much more marked than in the first generation. Kammerer's (37) experiments with *Alytes obstetricans* demonstrate a progressive increase in the efficiency of response to altered conditions in successive generations. In his experiments with *Salamandra maculosa* we again see a progressive increase in the response in successive generations. By reacting to the changing conditions of environment, in each case the individual in some way becomes attuned to them, *i. e.* acquires a capacity to react again, to react better and more efficiently and quickly if the altered conditions reappear. This is essentially the same as facilitation of the physiologist. This *attunement is inherited.* Individuals of organisms exposed to a new environment acquire modifications, primarily functional and secondarily structural, which adapt them to it. The offspring, if subjected to the same changed conditions of environment, acquire the same adaptations, indeed acquire them more quickly and to a more marked degree than their parents. Successive generations acquire the character to a progressively higher degree. This can only have one interpretation: *Some influence arising from the response of one generation to environmental conditions is being transmitted to the following generations and this influence is cumulative*—increases with the response of each successive generation.

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*Huff's (38 a) suspicion that Metalinkov's results represent 'selection' is precluded by the fact that selection actually results in diminution of acquired immunity rather than increase in successive generations.

The actual adaptations themselves are not inherited, but only the capacity to produce the adaptations. Acquired characters or the structural adaptations arising under the influence of the changing environmental conditions independent of genetic changes are temporary even during the life-time of the individual in which they arise, unless the structural alterations are very profound and unless the changed conditions continue to operate. Although acquired characters are temporary, the capacity to produce these characters nevertheless persists and endures much longer than the character itself and outlives the altered conditions that originally gave rise to the capacity. This capacity is inherited temporarily, so that it becomes more and more delicate and the character appears earlier and earlier in the life-history of the individual in successive generations until finally it arises in the embryonic development of the individual and is then said to be inherited in the ordinary sense.

In the light of this knowledge the contradictory results of numerous experiments so far carried out to prove or disprove the inheritance of acquired characters begin to find a natural explanation. Biologists have expected to find a direct inheritance of acquired characters, which never occurs and again they have looked for visible characters only. They seem to have utterly failed to recognize that it is not the visible characters that are inherited but only the capacity to produce the characters—the attunement to altered conditions of life. No animal inherits, for example, its limbs from the parents, but what it inherits is only the capacity to grow limbs similar to the ones possessed by them. It also becomes clear why mutilations are not inherited. By cutting off the tail of 1592 mice, Weismann by no means removed the need for the tail, but rather intensified the need. As will be shown further on, adaptation involves normal functioning inspite of enforced conditions. Indeed Weismann's mice should and could not have lost their tails at all, but if anything, should actually have had longer tails to the utter confusion of the silliest experimenter that biology ever produced.

The proof that somatic changes arising under the influence of the changing environment are inheriated, however indirectly, does not necessarily solve our difficulties. How are we to explain this in terms of our knowledge of the undoubted importance and significance of the chromosomes, genes, nuclear and cytoplasmic particles in development and heredity ? As often it happens, when two opposing schools of thought derive their basic ideas on equally sound experimental work, we may be sure that some vital and extremely relevant fact is being utterly overlooked by both sides. The conflict is entirely due to our stubborn refusal to give up the artificial distinction between soma and germ. Mechanical models have doubtless their great utility but are apt to be mistaken for the original. There is very urgent need for a complete re-orientation of our very way of thinking. We have to think of the organism as an indivisible, completely integrated unit, a unit not merely for ordinary functions of life but for all its functions, for inheritance as well. As we shall see further below, heredity is not the property of an imaginary germplasm, which does not in any case exist as distinct from the somatoplasm, but of the whole organism ; it is the characteristic of life itself. To assume otherwise is to betray total ignorance of the recent developments in biology, to which cytologists and geneticists themselves have contributed a great deal.

3. THE ORGANISM AS A UNIT

The living body presents the problem of unity or wholeness of a thing which is composed of separable parts. A living organism is a complete *causal* unit—it is a whole giant molecule which when divided ceases to exist as such. In Whitehead's (78,79,80) terminology adapted by Agar (1, 2) the organism is a *nexus* : "organization of parts dependent on the mutual action of parts on each other with the consequence that the whole acts as a causal unit both on its own parts and on other objects." The body is a nexus of organs and tissues ; the tissues of cells and the cells of subcellular self propagating cytoplasmic and nuclear systems. Every tissue, every cell including the germ cell, every chromosome and gene of every cell, indeed every self propagating "particle" is closely integrated in function and structure. *The function, development and growth of every cell are determined by and in turn determine those of every other cell.* No cell, not excluding the germ cell, is an isolated entity in the body, except under pathological conditions such as cancerous growths in plants and animals.

In the tissues the cells are not just naked protoplasm but more or less encapsulated in a ground substance, which is mostly a product of the cells themselves. The cells are however not isolated either structurally or functionally but are very closely connected together by the so-called plasmodesms of Strasburger or cytodesms of Studnicka, so that it is literally impossible to decide where one cell ends and where the other begins. As early as 1873, Heitzmann (31) drew attention to the fact that the cell walls are traversed through and through by fine protoplasmic strands, so that the whole body is one continuous mass. Indeed such protoplasmic connections have been demonstrated between individual blastomeres and in the germ layers as well as adult tissues. Andrews (3) and Gray (26) have, for example, demonstrated the undoubted existence of such fine protoplasmic bridges between the early blastomeres of Echinodermata. Numerous workers have similarly shown that the germ cells are connected to the neighbouring cells by protoplasmic strands both in plants and in animals. Sedgwick (62a) in 1894 pointed out that the entire body of an organism is in direct continuity : a syncitium. This conclusion is entirely in harmony with the work of several cytologists like Hammar (29), Wilson (84), Rauber (61), Whitmann (82), Ritter (62) and others. A series of observations by Fischer (23) on isolated tissue cells *in vitro* indicate that cytoplasmic connections between cells are of great fundamental importance to the cells. As Studnicka (71) has shown, the protoplasmatic interconnections between the cells in an organism are the lines of communications and are actually the main condition for the very existence of the cell as a living unit. The old idea of the organism as merely a colony of cells, which was a natural consequence of the classical cell theory of Schleiden and Schwann, has long ago been shown to be wholly erroneous (Whitmann, 82). As Carrel (7, 8) forcibly expressed, the organism is really one cell that has divided and become a multitude, at the same time as it has retained its unity. Meyer (52) described the organism as a continuous mass of protoplasm that forms a morphological unit, whether it appears as a single cell, a syncitium or as a system of cells. The Protozoa that are now described as acellular and present far greater complexity of structure than is often met with in the so-called multicellular animals, constitute, for example, a complete functional unit and are capable of carrying on all the varied functions of life just as any other plant or animal with complex tissues.

Fischer (21) found in the course of his brilliant tissue culture investigations that even the cultures of tissues isolated from an organism behave fully as whole organism-like, correlated systems rather than as independent colonies of cells. Isolated cells show a very high degree of cytotropism, which is an expression of the interplasmatic connections indicating high chemical affinity. Even the so-called unicellular animals possess this tendency to a remarkably high level of development. Pfeffer observed this behaviour in ciliates first and Jennings in 1936 describes it in the case of *Paramecium.* Another proof for the total integration of the cells is derived from every day experience. Mitosis for example is known to set in under the influence of autolysed nuclear substances produced by other cells, which are undergoing degenerative processes in the neighbourhood (20,35,27).

The results of tissue culture investigations on the significance of the interplasmatic bridges, physiological correlation of the cells, mechanism involved in limiting growth, morphological signs of organizations, polarity of cells and of tissues, regeneration of tissues and cells all abundantly establish the complete integration of every part of the organism into a functional whole. The results of tissue culture regeneration experiments, in particular with those tissues that have ceased to grow, show that like the living organisms, they are also closed systems. Similarly the recent studies on the embryology and morphogenesis of various organisms indicate that differentiation is incompatible with cell proliferation. This can only be explained on the basis of close integration of the cells into a functional whole. Carrel & Ebeling (8) have indeed demonstrated that substances which limit mitosis actually circulate in the blood of animals with advancing age and these substances arise from the cells themselves.

Recent investigations on the biology and chemistry of ageing (senescence) and on rejuvination also fully corroborate these conclusions. The changes that result in senescence are characterized by an increase in the growth-inhibiting substances which arise, as mentioned above, from the growing cells themselves and accumulate in the surrounding medium. The cells are old not because they have in any way lost their vitality or capacity for further growth and differentiation, but they are really prevented from growing any further by the accumulation of substances that inhibit mitosis.

The results of cancer research harmonize with the conception that in the living organism every tissue or cell is closely functionally integrated. In 1926 Burrows (5) showed, for example, that there is really no reversion to the embryonic state in neoplastic cells *but the latter are merely freed from the factors that compel them to function as a part of the organism.* The change is believed by him to be probably not within the cell itself but in its immediate environment. Differentiation and functioning take place under conditions unfavourable for growth. Growth depends on the concentration around the cells of substances—the so called *archusia*—produced the cells themselves. The exhaustive studies of Zuckermann (87) have fully demonstrated that all living cells produce substances which affect other cells in the body.

Evidence for the integral nature of organism comes also from observations carried out not for specially establishing the fact. Wigglesworth (83) has, for example, described one of his experiments on insect metamorphosis, in the course of which two decapitated insects are united, neck to neck. The epidermis of the two insects merge together and the two individuals moult simultaneously. If, however, the insects are connected up by means of a capillary tube so as to establish blood connection between the individuals, the moulting takes place independently of each other.

The organism as a whole is the sum-total not merely of its parts—the cells and tissues—but also of the relations between them, the actions, interactions and effects on each other or the physiological correlations. This physiological correlation is control and dominance on one side and of being controlled and dominated (subordination) on the other side. The physiological dominance appears right from the very early embryonic development, in which it is an essential factor : embryonic development is impossible in the absence of this physiological dominance and integration. The physiological dominance of one part over another is effected either by initiation and transmission of energy changes or by production and transport of chemical substances. The transmissive dominance includes production of mechanical, thermal or electrical changes leading on to excitation. Ordinary so-called undifferentiated protoplasm is itself capable of this, but the highest degree of this dominance is through the nervous system. The chemical dominance is closely bound up with differentiation and depends upon specific substances. That such chemical means of integration really occurs is now no longer to be doubted. In the physiological gradients and biological fields described by Child (10), the highest point in the gradient in a biological field is naturally the physiologically dominant part. The dominance decreases in effectiveness with increasing distance from this point and is due to decreasing concentration of the chemical substances that diffuse out. The range of effectiveness depends on the physiological and developmental conditions, so that sometimes parts somewhat on the fringe of the field exhibit a kind of physiological isolation that is closely associated with agamic patterns of development and reproduction in axiate organisms. From the mass of evidence collected together by Child from agamic reproduction in plants and animals and reconstitution of isolated pieces, it is clear that *physiological dominance maintains the individual* organism as an integrated unit.

That actual exchange of proteins, enzymes, catalysts and a variety of other chemical substances takes place between cells by way of the interplasmatic interconnections has long ago been established by several independent workers. In this process the circulating body fluids like sap and blood no doubt play a very significant role. The close relation between organic form and chemical constitution is now fully recognized and has been discussed at great length by Needham (55, 56, 57). Beginning with the now classical experiments of Spemann, a large series of brilliant investigations on the amphibian morphogenesis, especially the effect of dorsal blastopore lip, the chordamesoderm, the vertebrate eye, etc., by Spemann, Holtfreter, Bautzmann, Mangold, Fischel, Wehmeier, Krämer, Lewis, Waddington, D. M. Needham, J. Needham, Lemberg, Novinski, Woerdeman, Raven and on insect morphogenesis by Seidel, Bock and others have shown that chemodifferentiation precedes morphodifferentiation. Long before visible structural differences arise, we can recognize chemical and functional differences. *The chemodifferentiation arises in certain cells, but the materials from these cells activate or inhibit the neighbouring* *cells*. The material that achieves this has been isolated and shown to be related to sterols by Waddington and Needham (74). They succeeded in inducing neural tube formation by means of synthetic hydrocarbons of phenanthran-group, 1:9-Dimethylphenanthracene, 9:10-dihydroxy-, 9,10-di-n-butyl-, 9:10-dihydro-, 1:2:5:6-dibenzanthracene, etc. The recent demonstration by Brachet (4a) that in the evocation of neural tube there is a great preponderance RNA has a profound significance.

4. GENETICS *versus* UNITY OF ORGANISM

Progress in cytology, cytochemistry and genetics fully corrobaorates the unity of the organism. We see clearly that the integration involves not merely the various tissues and cells that compose the body of an organism, but also concerns the cell system itself. The subcellular agents are integrated in the common interphase viz. the cytoplasm. The nucleus obtains raw materials from the cytoplasm and to the cytoplasm it passes on the products of gene action. The cytoplasm is the locus of materialization of all reactions within the cell. All the self propagating, self synthesizing systems in the nucleus and cytoplasm are integrated by the cytoplasm. There is now hardly any doubt with regard to the close interdependence, interaction and co-operative action of the nuclear and cytoplasmic material (13, 16, 65). The genes of the same kind in all cells are identical and have the same structure and potentialities. Like genes of different cells therefore react alike to the same chemical changes. All the genes in the germ cells are then closely dependent on the function of the genes in the somatic cells. *Since the germ cells are bathed in the integrating chemical fluids of the body, the germ cell genes are subject to the same stresses as those of the somatic cells.* The changes in the cytoplasmic self propagating particles affect the nuclear genes, which react by stabilizing and controlling the altered cytoplasmic systems. The relation of the nucleus and cytoplasm is thus reciprocal. Further, we also know that the action of genes depends not only on the simultaneous actions of one another but also on what the genes have done before and in other parts of the body. In cancer cells, for example, Lewis (39,40) and Kemp (38) have shown that a permanent alteration, perhaps of a colloidal nature, in the cytoplasm (a mutation), arising independently of the nucleus, is later controlled and stabilized by the changed nucleus (15a, 38a). Even in healthy organisms we have evidence of the co-operation and interaction of cytoplasmic and nuclear material. Sonneborn (65-68), Preer (57) and others have demonstrated the existence of plasmagenes that control hereditary-traits not found in the nucleus. We have, for example, in *Paramecium aurelia* the plasmagene—kappa—in the cytoplasm not initiated by the nuclear gene (K) but not wholly independent of it.

These facts acquire a new significance in the light of the tremendous advance in recent years in our knowledge of the nucleic acids. Caspersson (9, 9a) has demonstrated that the nucleic acids of the nucleus (DNA & RNA) and those of the cytoplasm (mainly RNA) bring about the continuity of cytoplasm and nucleus. It is believed that DNA is synthesized at the expense of RNA in mitosis and this RNA is derived from cytoplasm. The nucleic acids play a very important role in the synthesis of proteins in the cell. This synthesis is initiated specially in the nucleus. The synthesis of gene proteins and cytoplasmic proteins is considered to be a kind of co-operative affair between the euchromatin and heterochromatin. In view of this fact, the role of nucleic acid in the nuclear division of mitosis is of far greater interest than even the protein synthesis (15). The interesting demonstration in 1936 by the Polish biologist, Konopacki that the nurse cells produce DNA, which is passed into the egg cell, is perhaps the most shattering evidence against Weismann's germplasm theory. Cooper from the United States recently showed that there is also in plants a similar transference of DNA from the nucleus of the nurse cells into the cytoplasm of egg cell, where it is ultimately destined to be built up into the haploid female nucleus. We have also complete proof of the infiltration of golgi elements from the follicular cells into the cytoplasm of the egg cells in various animals. *The relation between the nucleus and cytoplasm is thus a two-way affair*; the hereditary factors in the chromosomes govern the cell as a whole but the cytoplasm in turn influences the conditions within the nucleus and so modifies the activity of chromosomes and genes. The observations of Zuckermann (87) and others are now intelligible and we begin to perceive the precise means of integration of genes, nucleus, cytoplasm, cells, etc.

The organism is a unit, in which there is a physiological dominance over morphology: function over structure. The organism is a functional unit, no matter whether it is a complex multicellular body, a syncitium, a single cell or subcellular self propagating "particle". No part of the organism, neither the germ cell nor the gene, is a free agent. The life of the organism as a whole is not merely the sum-total of the activities of cells but also of their interrelations, interactions and effects on each other. The artificial distinction between a somatoplasm and a germplasm, a metabolic as distinct from a hereditary unit, which does not in reality exist, must be discarded. Breaking away from the hypnotic spell of Weismann's germplasm theory at once opens up a vast vista of facts that were so far unintelligible.

5. ADAPTATIONS

The foregoing discussion emphasizes one very important fact : *Nothing can happen in any part of an organism without affecting in some way or the other every other part and the organism as a whole*, in other words, the principle of functional dominance and subordination. Against this knowledge our ordinarily accepted notions on adaptations require profound modification.

Life itself is bound up with continual self synthesis of giant protein molecules by catalytic complex, characterized by transformation of energy. The process of self synthesis is the mechanism of utilization of energy. Such self synthesis or reproduction is integrated with a specific source of energy, usually some form of oxidation. The source of energy is in turn integrated with the kind of materials available in the surrounding, *i. e.* environment. Self propagation thus involves maintenance of the material requirements in an ever-changing environment. The integration of the genes in a common interphase, the cytoplasm, secures this contigency. The cytoplasm forms a sort of unchanging immediate environment in an ever-changing environment and provides the necessary conditions for self synthesis. In the resynthesis of the ultimate unit of living matter, which Hyndman (34) calls the *germ integer* (gene), there is an orderly retracement of the entire process of integration and this retracement proceeds by the same chemical operations and in the same chronological order by which the original germ integer was itself reached. The origin and development of the genes constitutes the first order differentiation of Hyndman. The integration of the genes in a common cytoplasmic immediate environment constitutes his second order of differentiation. In the third order of differentiation postulated by him we have the integration of the cells into the metazoan body or the "haploid" chromatin duplication within the cytoplasm giving rise to the Protozoan body.

Self synthesis in an ever-changing environment, as pointed out above, presupposes the maintenance of the material requirements and necessary conditions. The environmental changes affect firstly the material needed for retracement (resynthesis) and involves new materials, *food.* The impress of the environment is therefore *changing the nature of food.* The second effect involves unfavourable conditions, which Hyndman calls *abuttments.* The reaction to these changes is direct. Indirect reaction involves utilization of some factor like sunlight as aid to direct reaction.

If reproduction of the germ integer is so irrevocably contingent upon the same environmental conditions as the one in which it was organized, but as the environment is not fixed, the interphase that integrates the germ integers with the environment becomes the immediate unchanging inner environment for the germ integer. The impress of the changing environment is therefore first on the cytoplasm. The genes react only within the cytoplasmic environment (13, 50a, 85). All these actions and reactions are chemical ; the chemical differentiations later giving rise to visible structural differentiations. The cytoplasm thus reveals itself as the locus of materialization of all reactions to changing environmental conditions. The changes in the environmental conditions of an organism first act on the cytoplasm of the somatic cells and give rise to altered chemical conditions within it.These chemical changes arise independently of the genes but affect the genes. The genes react by stabilizing and controlling the altered cytoplasmic conditions in the group of cells on which the environmental changes made their direct impress. From these cells diffuse outward to every cell, including the germ cells, the chemical substances representing the changed conditions through the circulating sap, blood or other integrating mechanisms. Thus is drawn forth in every cell identical reactions from the corresponding genes. Every cell reacts as though it was itself directly impressed by the changing environmental conditions. If this were not so, modern genetics becomes meaningless. *The genetic changes are therefore primarily chemical and are not direct response to the environment, but to the effects of the environment on the somatic cytoplasm.* The genes do not react directly to the environment but only to the internal environment of cytoplasm. All genetic changes thus involve the maintenance of the cytoplasmic environment, viz. *adaptation.* The control of cytoplasm over the nucleus is most clearly seen in the synchronisation of mitosis and meiosis in groups of cells ; the cytoplasm is in immediate control of all details of mitosis.

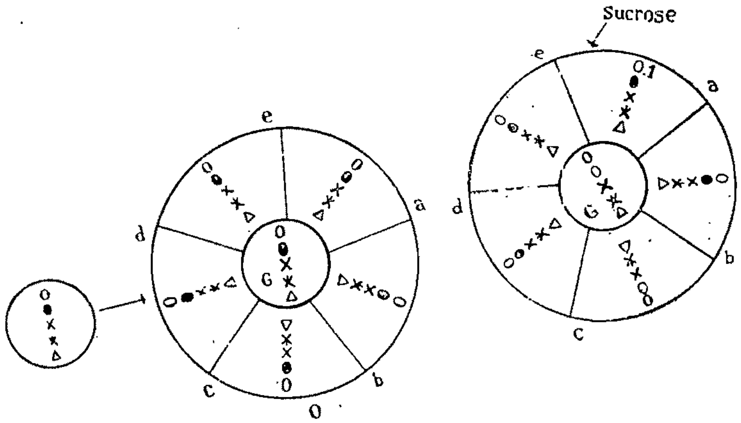

FIG. 1. Hyndman's diagram to elucidate the principle of adaptation under the influence of changing conditions of environment. To the left is the cell (P) that gives rise to the multicellular organism (6-celled) in the third order of differentiation. There are 5 genes, of which the homologues are omitted in the diagram for the sake of convenience. Changing environmental conditions in the shape of introduction of sucrose on cell (a) on the right cause the gene (0) to react and (0.1) indicates the consequent genetic change. (*After Hyndman*).

In further elucidation of the mechanism of adaptation we may follow the illustration from Hyndman. Assuming that we have a cell (P) with 5 genes (G Fig. 1) integrated in a diploid chromosome, we can readily see that by division, it gives rise to a multicellular unit represented in the figures as composed of 6 cells, of which the cells (a-e) are the somatic cells and the cell (G) is the germ, which is then the analogue of cell (P). The six-celled unit is an integrated organism. It has existed in an environment containing glucose, but due to changing environmental conditions, sucrose now predominates in the surroundings. Assume that only the cell (a) is exposed to this changed condition and therefore it alone responds. The cytoplasm of this cell receives now sucrose instead of glucose and one of the genes (0) reacts, with the result that an enzyme capable of converting sucrose into glucose arises in the cytoplasm. Let this genetic differentiation be represented by (P. 1). The chemical elements that diffuse from this cell evoke corresponding changes in corresponding genes of the other cells, which therefore differentiate as though they themselves received sucrose instead of glucose. The cell (a) pictured here may really be a group of cells differentiated into tissues and organs such as the alimentary canal, which thus becomes adapted to deal with sucrose instead of glucose. Similarly in the case of an organism exposed to an environment which is gradually growing more and more arid, the integumental cells are affected, the cytoplasm reacts, perhaps by secreting a protective waxy coating or by forming dark pigments (Fig. 2). The altered chemical materials representing these changes in the cytoplasm travel through all the cells. Since the (0) gene in all cells differentiate alike into (0.1), when the germ cell reproduces, every new cell it forms receives one (0.1) gene. It is however only the skin cells that differentiate by producing the wax or pigment, because they alone meet the specific change in the environment.

From this it follows that genetic changes cannot be the result of mere accidents; they are not spontaneous as supposed by the Mendel-Morgan geneticists. Genetic changes are directly correlated to the requirements—the changing conditions of life in the environment. They do not however arise as result of the direct impress of the environment on the germ but only indirectly to the changes in the somatic material caused by the environment. *Environment acts on the soma, the soma acts on the germ, the germ reacts and stabilizes the somatic changes.* The soma is thus a kind of internal environment. Adaptations thus arise in response to changing environment and are clearly inherited.

Here we have the explanation and also the mechanism for the inheritance of somatic changes arising under the influence of changing environment. The inheritance of attunement to the stimulus, the capacity to respond, demonstrated by Martin (50) becomes intelligible. By once reacting to a specific change of environmental conditions, the organism acquires the capacity to react again; this capacity is altered chemical conditions in the body. The chemical alteration takes place in the whole body of the organism, the germ only carries it forward. From the very nature of the processes involved, nothing is visible. If the altered conditions continue to operate, the organism is already prepared to produce the requisite adjustment.

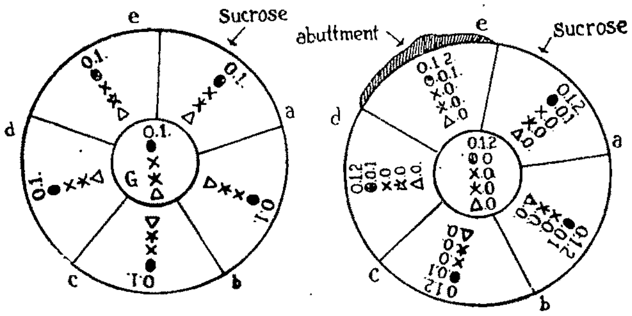

FIG. 2. All like genes in the body react to changing environment, viz. the introduction of sucrose at cell (a) and thus arise in all cells, including the germ cell (G), the genetic change (0.1). On the right is the illustration of an abuttment on cell (e) and the consequent genetic changes in all cells. (*After Hyndman*).

Here we have the mechanism for the inheritance of the so-called acquired characters. It is obvious that *all adaptative changes must arise under the influence of environment and these changes must all be heritable.* It looks as if Lamarck, who was ridiculed by von Baer and by Weismann, put more truth in his theory than he ever realized. Lamarck held that environment, by producing new *needs* changed the organism : new needs are met by new habits; new habits involve new uses and discontinuance of old uses or functions. It can only be surmised that Weismann probably never correctly understood Lamarck, to whom he attributes the idea of direct inheritance of acquired characters. Two essential points need amplification with regard to use-disuse. It is often erroneously assumed that the environment means only climate; by environment on the other hand is meant environment in *toto*. Furthermore, it is also supposed that the environment remains the same when new uses are occurring or dissuse is coming into force. This is seen in the familiar argument about the neck of the giraffe. The increased use of the neck that led to its elongation was not because the giraffe's ancestor preferred to eat the leaves from the crown of tall trees, leaving those closer at hand and nearer the ground. The ancestor indeed did not have to strain itself by stretching and stretching till it almost grew giddy. The foliage that suited it as food was then close at hand well within its reach, but the plants that had them were themselves evolving and gradually growing taller or were being equally gradually replaced by taller ones. The use and the elongation of the neck were concomittant and there was no element of choice. With regard to disuse, as for example, the loss of pigments and reduction or total loss of eyes in cavernicoulous animals, there is again the same erroneous idea. To begin with, the ancestors were fully equipped with eyes that could function and with pigments in the skin that could cut off light. The absence of light gradually affected the cells and their genetic makeup in successive generations of animals that were gradually living more and more in protected situations, leading to the ultimate disappearance of pigment on one side or reduction and loss of function of the eyes on the other side. The hill-stream fish, which was supposed to have been carried away to the sea by its entering a torrent (63), because to start with it did not possess the adaptations described by Hora (33), represents another example of confusion. Need it be emphasized that the origin of the hill-stream adaptations in the fish and origin of the hill-streams themselves went on hand-in-hand ? The fish was of course completely integrated and adjusted with the then environment ; streams were then not torrents, but vast tectonic, geological and climatic changes resulted in upheaval of portions of land. These changes were gradual and slowly sped up the stream. In a sense the stream itself "evolved" into a torrent, with all it contained—fish, insect, plants all alike. At any time the stream and its animal and plant life were fully adjusted and integrated : there was no disharmony. Nowhere do we see any disharmony between an organism and the environment to which it belongs, though in the words of White quoted earlier, the world must literally team with ill-fits, unfits and misfits ; there are no such anomalies in Nature. Ironically enough, Mendel-Morgan genetics, which has opposed lamarckism root and branch, has provided all the material evidence for the inheritance of acquired characters.

6. HEREDITY AND ITS VARIABILITY

If Darwin is popularly supposed to have "explained" evolution, Mendel is equally supposed to have completely "accounted" for inheritance in plants and animals. Actually however mendelism is no explanation at all : *it does not tell us as to what constitutes heredity, how it arises or how it varies.* Heredity is not merely reproduction of organisms similar to themselves ; this is just only one aspect of heredity. In mendelism we deal with organisms which are known to differ in heredity and cross them. All that we learn from mendelism is how many offspring resemble one parent or the other or differ. Further, as we have seen above, mendelism is built on a false foundation, because it ignores the characteristic property of living matter. Mendelian heredity does not therefore have any evolutionary significance.

What then is heredity ? How does it arise ? And how and why does it vary ? If the organism is a "whole", if variations arise in it under the influence of the changing environment and if the effect of these changes circulate in the body of the organism as material chemical atoms and molecules and impress themselves on the germ, then directly we see that heredity arises in the organism as a whole. *Heredity is the property of the entire organism as a unit*; whether it be a germ integer, acellular unit, a single cell or a complex of cells and tissues of the higher plants and animals. It cannot belong to a special hereditary substance as distinct from the organism, as maintained by the geneticists. In the 6-celled organism which we have pictured above, the adaptative mechanism operates continually. At the end of five generations, for example, each of the genes show differential responses to different environmental stimuli and the zygote would have the "chromosome map" shown in fig. 3. In the course of cleavage, the first adaptative change will retrace first and integrate all cells to the first vertical pattern and the whole development thus proceeds in the order in which the adaptations arose and till all the cells of the organism

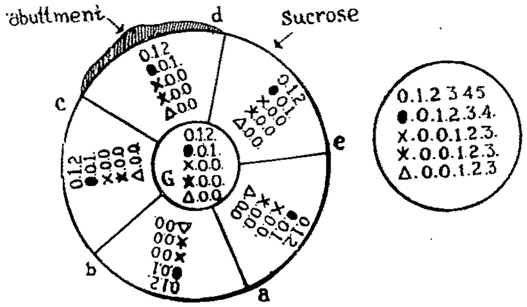

FIG. 3. On the left is the 6-celled organism with the genetic make-up at the end of the second cycle of resynthesis, as a result of the parallel changes in like genes in all cells. On the right is the zygote with its genetic make-up after 5 generations of the 6-celled organism. Each of the genes changes in successive generations and when the zygote undergoes cleavage, the body retraces and differentiates in the same chronological order, the first change coming on first, the second next and so. The zygote carries the genetic changes arising in the entire body cells. (*After Hyndman*).

conform to that order. Integration, differentiation and retracement are merely different phases of adaptation or maintenance of the conditions necessary for self synthesis in an ever-changing environment. *Heredity is thus the property of an organism to acquire definite conditions for life, development and resynthesis (reproduction) and to respond in a definite way to changing environmental conditions.* Heredity therefore is a manifestation of the effects of previous environment; hereditary differences in organisms are due to differences in the previous environment. This reads like a page torn from Lysenko (44, 45) and yet it is the *only* logical conclusion from Mendel-Morgan genetics. Lysenko has been in the right all the time. He has recognized what we appear to have wholly failed to see : "*Heredity is the effect of concentration of the action of environmental conditions assimilated by the organism in a series of preceding generations.*" Consequently to ascertain the environmental conditions required for the development of an organism is to study its heredity. This cannot naturally be achieved by crossing of the organism with another of a different heredity, as the mendelian geneticists do.

All the cumulative changes in the material, in the very chemistry of the organism arising in every part of it in the shape of adaptations become stored up in the zygote. *Heredity arises in* *the whole organism but is merely stored up in the germ which carries it forward ; the germ does not create heredity as is claimed by the geneticists.* Heredity cannot therefore be changed by poking into the germ ; the accidents that happen to the germ—the primary sources of variation, viz. mutations and rearragenements—cannot change heredity. The changing of heredity can only be accomplished in the entire body, in Weismann's soma. *The heritability of a change is contingent upon the relationship of the change to an adapting response : all heritable changes are therefore manifestations of adaptations.* The shape and structure of an organism may be changed in any number of ways but these changes need not be manifestations of adaptations. An organism does not adapt to enforced changes in form (Weismann's tail-cutting, for example) but it adapts in such a manner that it can maintain its requirements for resynthesis-retracement inspite of the forces causing the change. *Heredity thus changes only to changing needs: needs change by changing environment.* As Lysenko rightly observes, the cause of the change in heredity is a change in the type of assimilation, in the very metabolism type. Being included within and assimilated by the organism by the process of adaptation, the external environmental conditions cease to be external and become internal—a part and parcel of chemical make-up of the body. *The body of an organism is thus literally made up of environment : environmental materials snatched and synthesized and imprisoned in the body.* Changes in heredity are always adequate to the action of the environmental conditions. *Environmental, conditions are therefore the differentiating material, which are assimilated by the organism, which changes or differentiates itself.* No organism ever fully realizes or materializes all its hereditary potentialities; characters remain recessive and do not affect the development. The non-materialization of the full potentiality is again because of environment : lack of the various environmental conditions.

We should now realize the urgent need for discarding the sterile policy that we have so far followed and reopening discussion on basis of the unjustly discredited lamarckism. If Lysenko and other biologists behind the "iron curtain" speak of destabilizing heredity and directing the evolution of plants and animals by altering the environmental conditions, there is a great deal of deep meaning behind their "madness". By mendelism we can certainly mix and combine what there is, but cannot alter that or create what is there not. Lysenko's claim that food, being an environmental material, changes heredity is fully vindicated. Much that was obscure regarding the astonishing results of vegetative hybridization is explained readily on the basis of what has been discussed here. The remarkable achievements of Burbank (5), Michurin (53) and other Russian agrobiologists are not without profound significance and demand our closest study. Without perhaps realizing it, the geneticists, who are the bitterest opponents of Lysenko, seem to have themselves provided all the material in his support. All heritable changes being adaptive, there are no ill-fits, misfits and unfits to weed out and we can now afford to forget "natural selection" and "mutations" will themselves vanish when the conditions in biology return to the normal.

7. CONCLUSIONS

The organism is a "whole"—a unit composed of integrated units. It is the sum-total not merely of the parts that compose it, but also of their actions, interactions and effects on each other in the past and in the present. It is characterized by dominance of function over structure. No change can occur in any part of the organism without affecting every other part and the organism as a whole.

The organism builds itself out of the environment and is closely integrated with it ; it is a part of the environment. Life is merely a property of matter that at a certain complexity of chemical composition synthesizes another molecule similar to itself. This self synthesis is based on catalytic complex and is dependent on the materials in the environment. Self synthesis in an ever changing environment introduces differentiation, an interphase that maintains the necessary conditions for resynthesis. Differentiation and integration operate continually resynthesis after resynthesis. The accumulated effect of the changing environment constitutes heredity. What is inherited is a series of material changes in the integrating interphase, viz. cytoplasm and body. Heredity is thus a property of living matter—of the entire body and all that it contains, sap, blood and literally every drop or particle.

Heredity changes in the whole body if the environment changes; the germ only gathers together the changes and carries them forward. Chemodifferentiation arising from functional differentiation precedes and determines morphodifferentiation.

Changing environmental conditions are *accompanied* by changing needs, changing needs by changing functions, which alter the the internal environment and this in turn heredity. Variations in heredity are manifestations of adaptations. Adaptations therefore arise under the influence of changing environment and are heritable. *The accumulation of adaptations constitutes descent with change or evolution.* Heredity cannot be changed except by changing the environmental needs of the organism. *Changes that arise without reference to the needs—mutations—are not adaptations and are of no value in evolution.* Variations that are the raw materials of evolution are therefore not due to chance or accident. The randomness of the geneticist does not exist; nevertheless changes in heredity are statistically random, and doubtless conform to the familiar 'frequency distribution normal curve' pattern because they arise under the influence of numerous co-existing factors, and not because of meaningless random dealing of pairs of 'hereditary' particles. Evolutionary changes are not causeless; the ceaseless chain of *cause* and *effect*—environmental changes and adaptations—grips evolution; the endless chain of cause and effect contained in the *karma* theory of the sages of ancient India.

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DESCRIPTIONS OF NEW AND RECORDS OF SOME KNOWN PARASITIC HYMENOPTERA FROM INDIA*

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This paper is a report of my study of a small collection of Parasitic Hymenoptera received for identification from B. Krishnamurthi, Government Entomologist, Department of Agriculture, Bangalore. The type specimens of the new forms described here are all for the time being retained in the School of Entomology.

I thank Dr. M. S. Mani, Professor of Zoology and Entomology, for placing this material at my disposal and for guidance.

Superfamily CHALCIDOIDEA

Family *CHALCIDIDAE*

Subfamily HALTICHELLINAE

Hockeria atra Masi

1929. *Hockeria atra*, Masi, *Boll. Lab. Ent. Bologna*, **2** : 180.
1934. *Hockeria atra*, Ramakrishna and Margabandhu, *J. Bombay nat. Hist. Soc.*, 37 : 194.

I refer to this species a series of males and females labelled : "Ex. *Corcyra* pupae, Bangalore, 1952, M. Appanna". This has formerly been recorded from Puri.

Family *MISCOGASTERIDAE*

Subfamily BRUCHOBIINAE

Bruchobius vagabundus (Timberlake)

1926. *Bruchobius vagabundus*, Timberlake, *Proc. Hawaii ent. Soc.*, 6: 305-320.
1939. *Bruchobius vagabundus*: Mani, *Indian J. Ent.*, **1** (1&2) p. 69-99.

I refer to this species a series of males and females labelled : "Ex. Bruchid larvae, Bangalore, 1952, A. Appanna."

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This species is known to parasitize *Bruchus quadrimaculatus* in Hawaii and *Bruchus chinensis* in Bangalore.

Family *ENTEDONTIDAE*

Subfamily OMPHALINAE

Achrysocharis appannai, sp. nov.

Female.—Length: 0.7 mm. Colour: reddish-brown to black. Head viewed from above transverse, length two-sevenths the breadth; interorbital distance very slightly over half the breadth of the head ; ocelli reddish-brown, interocellar distance one and one-third the ocellocular which latter is thrice the front ocellar; apex of scape reach the anterior ocellus ; vertex narrow, smooth and shiny. Viewed in front length slightly more than the breadth, which latter is two and four-fifths the interorbital; length of eye nearly twice that of gena and slightly more than twice that of post-orbital; clypeus yellowish-brown, smooth and shiny; mandibles same colour as clypeus, three dentate, first two teeth acute, the last blunt. Antenna brown, inserted slightly below the middle of face, somewhat above an imaginary line joining the lower orbital borders; 9-segmented; scape, pedicel, one ring joint, 3-segmented funicle and triarticulate club ; scape and pedicel yellowish-brown, rest of antenna brown ; scape twice the pedicel, which latter is slightly longer than the first funicular and equal to ring joint and first funicular combined ; second funicular longer than the first and very slightly longer than the pedicel; third funicular longer than second and four-sevenths the scape ; first two club joints equal ; third two-thirds the previous ones ; all club joints together slightly longer than the scape (Fig. 3).

Thorax: Length one and one-fourth the breadth at the region of the tegulae; pronotum short ; mesonotum slightly less than half the whole length of thorax, finely longitudinally coriaceously striate; parapsidal furrows deep and complete; scutellum six-sevenths the mesonotum, convex, sculpture same as that of mesonotum ; metanotum one-third the scutellum ; propodeum two-thirds the scutellum, irregularly coriaceously sculptured, with a median longitudinal carina which bifurcates posteriorly enclosing a triangular area. Legs yellowish-brown. Hind coxa twice the trochanter ; femur three and a half times the trochanter ; tibia one and one-fifth the femur ; metatarsus one-sixth the tibia and oen and one-fourth the tibial spur; rest of tarsi combined slightly more than half the tibia and nearly three and a half times the metatarsus (Fig. 4). Fore wing length two and one-fourth the breadth ; submarginal slightly more than two-thirds the marginal, which latter is three and a half times the stigmal; apical pubescence somewhat long (Fig. 1 &2). Abdomen very slightly longer than thorax, brown to dark reddish-brown; eight tergites visible; first and second tergites longer than the rest and are light brown ; rest of abdomen darker.

Male.—Length : 0.7 mm. Colour : reddish-brown to black. Head viewed from above transverse, length slightly less than two-fifths the breadth ; interorbital distance half the breadth of the head ; ocelli brick red, large, arranged in a triangle; interocellar distance one and a half times the ocellocular which latter is twice the front ocellar; vertex narrow, sculpture not very clear ; eyes brown, bare, inner border of eye margined ; frons and face brown, faintly very irregularly sculptured or nearly smooth and shiny ; viewed in front, length very slightly more than the breadth ; interorbital distance two-fifths the breadth of the head ; length of eye nearly thrice that of gena and two and a half times that of postorbital distance; clypeus yellowish-brown; mandibles concolorous with the clypeus, 3-dentate, first two teeth acute, the last blunt. Antenna brown, inserted slightly below the middle of face, somewhat above an imaginary line joining the lower orbital borders ; 9-segmented; scape, pedicel, four segmented funicle and triarticulate club ; scape light brown, twice the pedicel; pedicel slightly more than one and one-third the first funicular; second funicular slightly more than one and a half times the first; third and fourth equal to the second ; first two club joints equal, third two-thirds the second ; all the three club joints together six-sevenths the scape and three-fourths the third and fourth funicular segments combined (Fig. 7). Thorax: Length one and one-fourth the breadth; pronotum very short; mesonotum three and a half times the pronotum, very faintly smooth and shiny ; parapsidal furrows complete and distinct ; scutellum slightly shorter than mesonotum, longitudinally coriaceously striate; metanotum one-fourth the scutellum; propodeum two-thirds the scutellum. Legs yellowish brown. Hind coxa nearly two and a half times the trochanter; femur one and two-thirds the coxa; tibia one and a half times the femur; tibial spur one-seventh tibia and very slightly longer than metatarsus; the rest of tarsi combined being equal to half the tibia and five times the metatarsus (Fig. 8). Fore wing length two and one-fourth the breadth; submarginal five-sixths the marginal, which latter is three and a half times the stigmal; postmarginal absent; apical marginal pubescence somewhat long (Fig. 5 &6). Abdomen very slightly shorter than thorax, somewhat dorsally flattened; eight tergites visible.

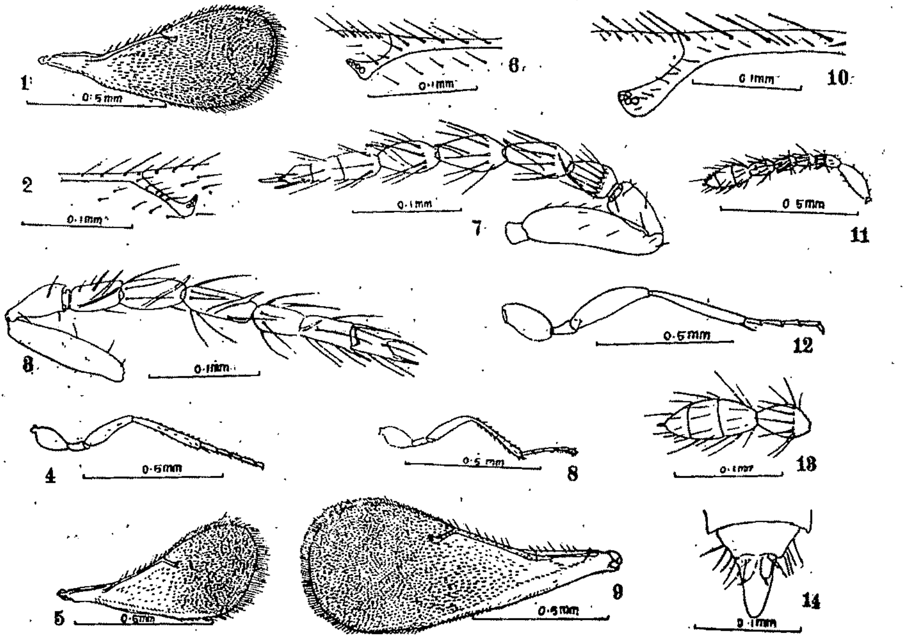

FIG. 1-4. *Achrysocharis appannai*, sp. nov. Female. 1. fore wing, 2. stigma of fore wing enlarged, 3. antenna, 4. hind leg.

FIG. 5-8. *Achrysocharis appannai*, sp. nov. Male. 5. fore wing, 6. stigma of fore wing enlarged, 7. antenna, 8. hind leg.

FIG. 9-14. *Tetrastichus sexmaculatus*, sp. nov. Male. 9. fore wing, 10. stigma of fore wing enlarged 11. antenna, 12. hind leg, 13. apex of antenna enlarged, 14. genitalia.

Holotype female dissected and mounted on slide No. 933/c; *allotype* male dissected and mounted on slide No. 933/c; *paratypes* many females and males in spirit, labelled: "Ex. *Epilachna* eggs, Bangalore, 1952, M. Appanna."

This is the first record of the genus from India.

Family *TETRASTICHIDAE*

Subfamily TETRASTICHINAE

Tetrastichus sexmaculatus, sp. nov.

Male.—Length : 1.4 mm. Colour : Black with a faint greenish lustre. Head black, with a faint metallic blue lustre in certain angles. Viewed from above transverse, twice as broad as long; interorbital distance two-thirds the width of the head ; post-orbital space nearly obsolete ; vertex narrow ; irregularly, finely punctate; ocelli reddish-brown, arranged in a curved line; interocellar distance one and three-fourths the ocellocular, which latter is one and one-third the front ocellar ; eyes brick red,bare ; viewed in front nearly orbicular, slightly wider than long (Fig. 16); interorbital distance nearly half the width of the head ; length of eye nearly one and a half times that of gena ; frons and face dark reddish-brown to black, with a faint metallic lustre in certain angles ; face faintly rugosely sculptured ; scrobes conspicuous with a distinct carinate ridge in between; genal suture distinct ; clypeus slightly convex ; mandibles reddish-brown, small, minutely and acutely bidentate at apex. Antenna inserted below an imaginary line joining the lower orbital borders ; brown ; 9-segmented ; scape, pedicel, four segmented funicle and triarticulate club ; scape two and a half times the pedicel ; first funicular two-thirds the pedicel ; second funicular slightly less than twice the ring joint ; third and fourth funicular segments gradually become longer ; first joint of club slightly shorter than the last funicular ; second nearly six-sevenths the first club joint ; terminal very slightly over half the latter, with a short nipple-like process towards the apex ; rest of details and setation as in fig. 11 & 13. Thorax : Prothorax short, conical, anteriorly narrowing, roughly, irregularly rugulose sculptured; mesothorax thrice the prothorax; parapsidal furrows deep, broad and complete ; black, with a slight greenish-metallic lustre in some angles, with shallow scale-like reticulation; scutellum two-thirds the mesothorax, slightly convex, concolouress and sculptured as in mesothorax, with two longitudinal furrows; metathorax short, sculpture same as that of pronotum; propodeum three-fourths the length of scutellum, finely irregularly sculptured, with a greenish lustre, median longitudinal carina running to two-thirds of the propodeum joining the transverse carina appearing as if it divides into two branches, enclosing a broadly triangular area posteriorly ; propodeal spiracles medium sized, spherical, close to but not touching the anterior margin of the propodeum ; paraspiracular carina present ; setation of mesonotum and scutellum as in fig. 15. Legs brownish-black, with the tips of the femur and tibia and tarsi brown ; hind coxa nearly two and a half times the trochanter; femur about twice the coxa; tibia one and one-fourth the femur; metatarsus one-eighth the tibia and one-fourth the rest of tarsi combined ; tibial spur nearly equal to or very slightly longer than metatarsus (Fig. 12). Fore wing length two and one-fourth the breadth ; submarginal nearly one and one-fourth marginal, with seven strong setae ; marginal with eight setae ; stigmal very slightly more than one-third the marginal ; post-marginal absent (Fig. 9 &10). Abdomen same length as thorax, black with bluish-green lustre, faintly, finely shagreened, with few scattered, short, brownish setae ; six tergites distinctly visible ; first the largest ; rest of them become shorter and narrower ; apex conical ; genitalia as in fig. 14.

Female.—Length : 1.6 mm. Colour : Black with a faint greenish lustre. Head viewed from above length one-third the breadth ; interorbital distance two-thirds the breadth of the head ; post-orbital distance slightly less than half the width of eye; Eyes dark brown, bare; vertex narrow, emarginate, dull and smooth, with a few scattered setae ; ocelli reddish-brown, arranged in a broad triangle ; interocellar distance two and a half times the front ocellar, which latter is three-fifths the ocellocular ; viewed in front length three-fourths the breadth ; interorbital distance nearly two-thirds the breadth of the head; post-orbital very little or nil; length of gena five-sevenths that of eye; frons and face very faintly and finely sculptured, nearly smoot hand shiny, with a faint metallic green lustre ; clypeus slightly convex, scupture same as that of face, truncate at apex ; mandibles short, dark reddish-brown, three toothed, first distinctly acute, second somewhat acute and third completely blunt; antennal foveae distinct on the face and frons and extends up to the anterior ocellus. Antenna dark brown, with short, stiff, silvery-brown pubescence, inserted above clypeus, below the middle of face, just above an imaginary line joining the lower orbital borders; 9-sgemented; scape, pedicel, one ring joint, three segmented funicle and triarticulate club ; scape cylindrical, nearly as long as pedicel, ring joint and first two funicular segments combined ; pedicel very slightly less than one-third the scape ; ring joint one-sixth the pedicel ; first funicular as long as the pedicel ; second one and one-fourth the first ; third equal to second; first and second club joints subequal and are equal to pedicel, third three-fourths the second; all club joints together five-sixths the scape and slightly longer than the last two funicular segments combined ; a nipple-like process found on the apex of the club (Fig. 17 &18). Thorax : Length somewhat more than one and one-third the breadth at the region of the tegulae ; pronotum short; mesonotum slightly over one-third the whole length of the thorax, very faintly coriaceously

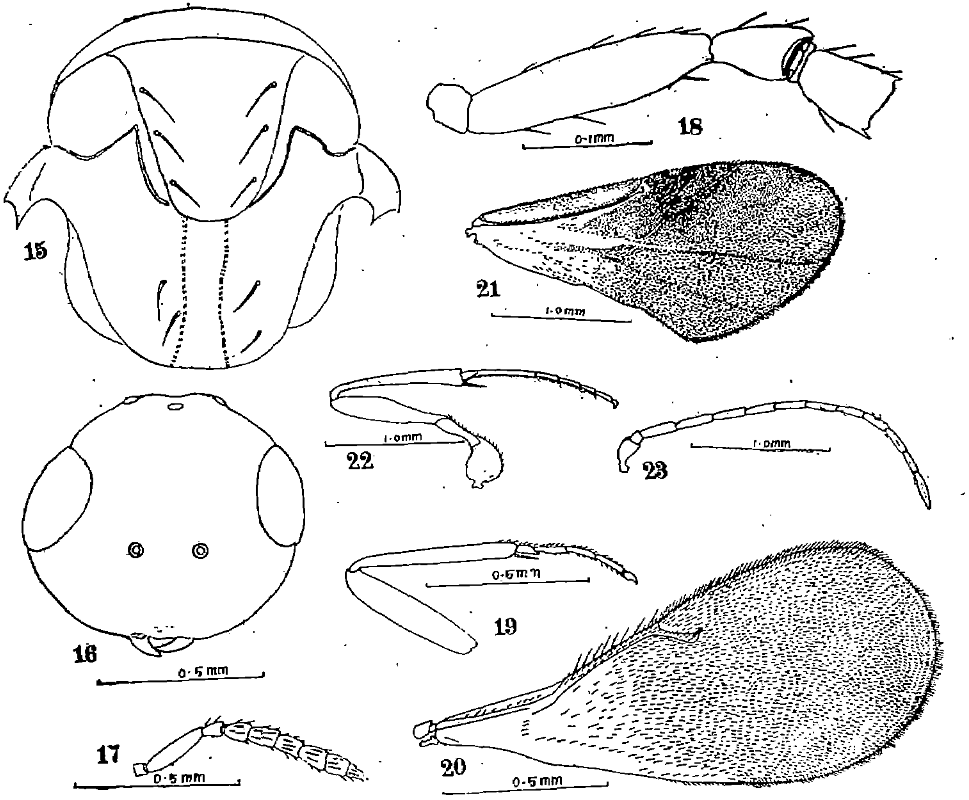

FIG. 15-16. *Tetrastichus sexmaculatus*, sp. nov. Male. 15. mesonotum and scutellum showing the setation, 16. head viewed in front.

FIG. 17-20. *Tetrastichus sexmaculatus*, sp. nov. Female. 17. antenna, 18. basal segments of antenna enlarged, 19. hind leg, 20. wing.

FIG. 21-23. *Phaenoglyphis bangalorensis*, sp. nov. Female. 21. wing, 22. hind leg, 23. antenna

sculptured ; parapsidal furrows deep and complete; scutellum equal to mesonotum, convex, coriaceously longitudinally striate, with two faint lateral longitudinal lines; metathorax short, one-fifth the scutellum, nearly smooth and shiny; propodeum four-fifths the scutellum, faintly irregularly coriaceously sculptured, with a median longitudinal carina which bifurcates posteriorly enclosing a triangular area; propodeal spiracles small and round. Mid coxa nearly one and a half times the trochanter ; femur two and one-third the trochanter and equal to coxa and trochanter combined; tibia one and one-third the femur; tibial-spur one-sixth the tibia and very slightly longer than the metatarsus; rest of tarsi combined nearly four times the metatarsus. Hind coxa one and a half times the trochanter; femur slightly over two and a half times the trochanter; tibia one and one-sixth the femur; tibial spur very slightly less than one-sixth the tibia and one and one-third the metatarsus; metatarsus one-ninth the tibia and one-fifth the rest of tarsi combined (Fig. 19). Fore wing length two and one-fourth the breadth; submarginal one and one-fourth the marginal, which is nearly thrice the stigmal ; post-marginal absent, rest of details and pubescence as in fig. 20. Abdomen seven-eighths the thorax, nearly round ; six tergites visible, the first the largest and nearly thrice the rest, which are nearly subequal ; tergites nearly smooth and shiny with a few scattered silverywhite pubescence, except the first which has a faintly shagreened appearance.

Holotype male dissected and mounted on slide No. 934/c ; *allotype* female dissected and mounted on slide No. 935/c(b) ; *paratypes* many males and females in spirit labelled: "Ex. *Chilomenes sexmaculata* grubs, Bangalore, August 1952, Coll: G.P. Channabasavanna."

This species runs close to *Tetrastichus melanis* Burks, from which it differs in having the second funicle slightly less than twice the first, third and fourth subequal; club slightly shorter than two apical funicle segments and mesonotum with only three pairs of setae.

Family *ENCYRTIDAE*

Subfamily MIRINAE

Homolotylus flaminius (Dalman)

1820. *Encyrtus flaminius*, Dalman, *Svensk. Vet. Akad. Handl.* **41** : 340.
1909. *Homolotylus flaminius*, Schmied., *Gen., Ins.* Fas., **97** : 235.
1934. *Homolotylus flaminius*, Ramakrishna and Margabandhu, *J. Bombay nat. Hist. Soc.*, **37** : 194.
1938. *Homolotylus flaminius*, Mani, *Cat. Indian Ins.*, **23** : 89.
1940. *Homolotylus flaminius*, Pruthi and Mani, *I. C. A. R. Misc. Bull.*, **30**: 14.

I refer to this species several males and females labelled: "Parasitic on *Chilomenes sexmaculata* grubs, Bangalore, August 1952, G. P. Channabasavanna". Mani recorded this species to be parasitic on the larvae and pupae of *Adonia variegata*, and *Brumus suturalis* at Delhi and *Chilocorus* sp. at Bangalore and Delhi and *Novius guerni* at Coimbatore. Bhatnagar recorded it from the larvae of *Rodolia cardinalis* and *Rodolia* sp. predaceous on *Icerya purchasi* at Bangalore. Mani and Kurian* recorded it from *Chilomenes sexmaculata* predaceous on aphids on cabbage and *Chilocorus* sp. predacious on *Lecanium* sp. on jack.

Homolotylus mexicanus Timberlake

1919. *Homolotylus mexicanus*, Timberlake, *Proc. U. S. Nat. Mus.*, **56** (2293) : 155.

I refer to this species 6 females bred at Bangalore on *Chilocorus nigritus* grubs. This is known to parasitize *Ceroputo yuccae* on agave in Mexico. This is the first record of this species from India. Males are not known.

Superfamily SERPHOIDEA

Family *SCELIONIDAE*

Subfamily SCELIONINAE

Scelio hieroglyphi Timberlake

1932. *Scelio hieroglyphi*, Timberlake, *Proc. Hawaii. ent. Soc.*, **8** : 175.
1941. *Scelio hieroglyphi*, Mani, *Cat. Indian Ins.*, **26** : 23.
1942. *Scelio hieroglyphi*, Pruthi and Mani, *Mem. Indian Mus.*, **13** (4) : 416, fig. **9**.

I refer to this spp. 2 females & 5 males bred from eggs of

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* Mani and Kurian 1953. *Indian J. Ent.*, 15 (1).

Hieroglyphus banian at Bangalore. This species is formerly reared at Coimbatore on eggs of *Hieroglyphus banian.* Rao[1] redescribed species reared by M. L. Roonwal at Ajmer from eggs of *Hieroglyphus nigrorepletus*. In a recent paper Mukerji[2] erroneously credits this species to Girault, who never published a description. According to the International Rules of Zoological Nomenclature, Timberlake is the protologist. Mukerji has further separated *Scelio oviphagus* as a species distinct from *Scelio hieroglyphi* Timberlake ; in the absence of Mukerji's type specimens it is not possible to correctly evaluate the material.

Superfamily CYNIPOIDEA

Family *CYNIPIDAE*

Subfamily CHARIPINAE

Phaenoglyphis bangalorensis, sp. nov.

Female.—Length : 3.5-3.75 mm. Colour : Black. Head viewed from above transverse, length somewhat less than one-third the breadth ; interorbital distance three-fourths the width of the head ; width of eye five times the post-orbital distance ; vertex narrow, smooth and shiny, faintly margined ; occiput smooth and shiny, slightly excavate; ocelli reddish-brown, arranged in a triangle ; interocellar distance nearly twice the ocellocular, which latter is one and one-fourth the front ocellar ; ocellar diameter two-thirds the front ocellar distance ; inner to posterior ocelli are two horn-like processes directed upwards one on either side ; viewed in front length two-thirds the breadth ; interorbital distance somewhat less than two-thirds the breadth of the head, inner orbital border very slightly diverging posteriorly ; length of eye twice that of gena ; frons and face smooth and shiny. Eyes reddish-brown, bare. Clypeus anteriorly rounded with a median depression anteriorly placed ; clypeus and gena covered over by somewhat dense silvery-white pubescence ; maxillary palpi four segmented, first two short, the last two long, second palpal segment is somewhat flattened

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[1] RAO, S. N. 1952. *J. Zool. Soc. India*, **3** (2) : 239.

[2] MUKERJI, S. 1952. *Indian J. Ent.*, **14** (3) : 203- 213.

out ; labial palpi two segmented and short. Antenna reddish-brown with darker apex, inserted slightly below the middle of face, just on or slightly above an imaginary line joining the lower orbital borders ; 13-segmented ; scape , pedicel, ten segmented funicle and entire club ; scape approximately twice the pedicel ; first funicular very slightly less than three and a half times the pedicel and slightly more than one and a half times the scape ; second and succeeding funicular segments gradually become shorter the last funicular being nearly equal to the scape ; club one and a half times the scape , three and one-fifth the pedicel and one and three-fifths the penultimate segment (Fig. 23). Thorax : Black, length slightly over one and a half times the breadth; prothorax short, laterally broadened, anteriorly with angular corners ; mesothorax nearly half the whole length of thorax, smooth and shiny except for short, scattered, silvery-white pubescence ; parapsidal furrows deep and complete ; lateral to parapsidal furrows are two deep and broad foveae one on either side, with many deep and broad pits in it, which coalesce with parapsidal furrows posteriorly and the apex slightly broadening out, but not reaching the posterior margin of mesothorax, tegulae reddish-brown ; scutellum rounded and bulging, with three broad deep pits anteriorly and smaller pits posteriorly placed ; metathorax differentiated from propodeum by a deep transverse fovea with many deep pits ; propodeum somewhat shorter than mesothorax, with a very rough reticulately carinate sculpture ; the irregular and branching carinae on the propodeum slightly diverge anteriorly ; propodeal spiracles large and lanceolate. Legs reddish-brown except for the darker coxae and the last tarsal segments. Fore coxa slightly longer than trochanter ; femur thrice the trochanter ; tibia very slightly shorter than femur ; tibial spur one-fifth the tibia ; metatarsus half the tibia and three-fourths the rest of tarsi combined. Mid coxa approximately three-fourths the trochanter ; femur one and a half times the coxa and trochanter combined ; tibia equal to femur ; the larger tibial spur one-fifth the tibia and the smaller two-thirds the larger ; metatarsus slightly less than half the tibia and two-thirds the rest of tarsi combined. Hind coxa equal to trochanter; femur one and a half times the coxa and trochanter combined; tibia one and one-seventh the femur ; the larger tibial spur slightly over one-sixth the tibia and the smaller nearly three-fourths the larger ; metatarsus somewhat less than half the tibia and slightly over two-thirds the rest of tarsi combined (Fig. 22). Fore wing length two and one-fifth the breadth ; subcosta long, somewhat less than half the length of the wing ; radial vein short, slightly shorter than one-third the subcosta, curved up enclosing a radial cell ; the area at the apex of subcosta surrounded by radius is clouded ; rest of the details as in fig. 21. Abdomen black ; as long as thorax ; smooth and shiny, laterally somewhat flattened, with a very short petiole which is the first tergite ; second tergite very large and covers nearly three-fourths the whole length of abdomen ; third somewhat less than one-third the second ; fourth very short ; ovipositor sheath twice the fourth tergite.

Holotype Female dissected and mounted on slide No. 406/H; *Paratypes* 1 female dissected and mounted on slide No. 406/H and 4 females in spirit labelled : "Ex. *Chilomenes sexmaculata*, Bangalore, August 1952, Coll. G. P. Channabasavanna". This is the first record of the genus from India. The other known species of the genus are parasitic on Braconids within aphids.

PRELIMINARY NOTES ON THE EARLY EMBRYONIC DEVELOPMENT OF *MYLABRIS PUSTULATA* Thunb. (Coleoptera)*

By S. R. DEOBHAKTA, M. SC., *Ministry of Education, Government of India Research Scholar, School of Entomology, St. John's College, Agra.*

INTRODUCTION

In this note are recorded the results of preliminary investigations on the early embryology of *Mylabris pustulata* up to the formation of the germ band. My object in selecting this insect for embryological studies is to provide a suitable material for teaching of insect embryology in our colleges and universities. Although we have excellent account of the embryonic development of various insects like grass-hopper, desert locust, etc., they are not quite suitable for use in post-graduate work in the Indian Universities. The eggs of the desert locust, the embryology of which has been beautifully investigated by Roonwal, are not available at all times in most parts of the country. There are also other technical difficulties which preclude the use of other insects as type material for embrylogical work in class-rooms. *Mylabris pustulata* is, however, abundant throughout the country nearly all the year round. Its eggs can be easily secured and sectioned with comparative ease. It is therefore a highly suitable material.

Although insect embryology has made rapid progress in recent years, comparatively little attention seems to have been paid to Coleoptera. Perhaps the earliest embryological study on Coleoptera was by Heider (13, 14, 15), who has given us a fairly detailed account of the embryonic development of *Hydrophilus piceus*. Nusbaum (26,27) published some observations on the formation of the germ layers and the segmentation of the germ-band in Meloid beetles. A fuller account of the embryonic development of *Melolantha vulgaris* was given by Voeltzkow (34). Notes on embryonic development of some Chrysomelids were published by Lecaillon (23). During the present century a nearly complete account of the embryonic development of *Dytiscus marginalis* was published by Blunk (1). Hegner (9, 10, 11, 12) has contributed materially to our knowledge of experimental embryology, with special reference to Coleoptera and in more recent years Seidler (33) has investigated the structure of the egg in Coleoptera. Among the other important embryological work of the order may be mentioned those of Brauer (2) on *Bruchus quadrimaculatus*, Butt (4) on the alfa-alfa beetle, Inkmann (20) on *Calendra granaria*, Mansour (25) *Calendra oryzae*, Paterson on *Euryope terminalis*, Wray (36) on *Calendra callosa*, etc.

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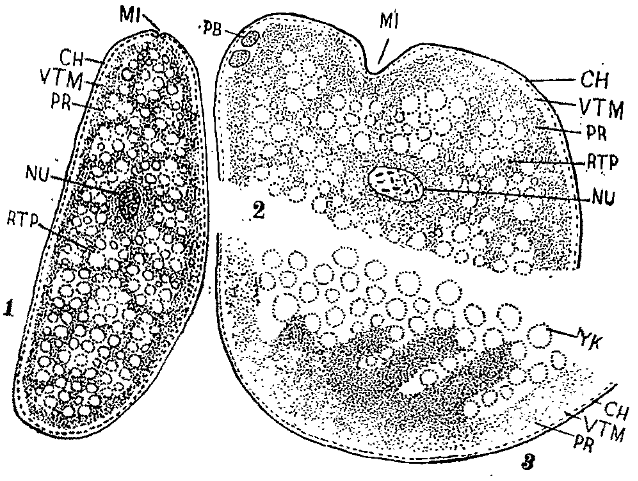


FIG. 1. Longitudinal section of ovarian egg.
FIG. 2. Longitudinal section of ovarian egg through the anterior end showing the maturation division.
FIG. 3. Longitudinal section of ovarian egg through the posterior end showing the oösome. CH Chorion, MI Micropyle, NU Nucleus, PR Periplasm, RTP Reticuloplasm; VTM Vitelline membrane, YK Yolk.

METHODS

The eggs are easily obtained by keeping the living beetles with sufficient food in a suitable incubator at a temperature of about 35°C. The eggs were incubated at a slightly lower temperature and were fixed at 18, 24, 48, 72 hrs. Fixing at shorter intervals, particularly on the first day after the oviposition, would be required in order to secure material representing the changes immediately following cleavage. Eggs from the ovary of mature and mated beetles are also fixed. Owing to great abundance of yolk fixing has to be done carefully. It was found that the fixative recommended by Seidler viz. Petrunkewitch fluid gave the best results. It is prepared by mixing 300 parts of distilled water, 200 parts of absolute alcohol, 90 parts of acetic acid, 10 parts of concentrated nitric acid and corrosive sublimate to saturation. Fixing is carried out at 60° C for half an hour but at room temperature for about six hours. Treatment with this fixative preserves the distinctive characters of the yolk and the protoplasmic material. After fixing the excess of sublimate was removed by 70% alcohol, in which the material is finally preserved. Imbedding is done in paraffin wax in the usual way and serial sections 8 micra thick were cut. Penetration of the wax is greatly facilitated and section cutting improved by treating the fixed eggs in carbolic acid. The eggs

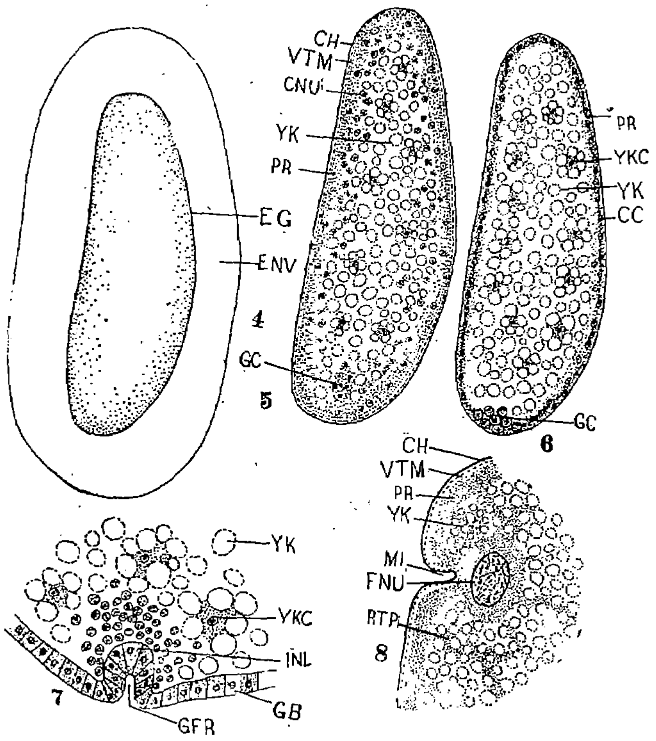


FIG. 4. Freshly laid egg with the envelope.
FIG. 5. Longitudinal section of the egg showing the early cleavage.
FIG. 6. Longitudinal section of the egg at a later stage of cleavage.
FIG. 7. Transverse section of the egg showing the gastrular furrow (posterior end).
FIG. 8. Longitudinal section of the egg soon after the fertilization showing the fusion nucleus. CC Cleavage cells, CH Chorion, CNU Cleavage nuclei, EG Egg, ENV Envelope, FNU Fusion nucleus, GC Germ cells, GFR Gastrular furrow, INL Inner layer, MI Micropyle, PR Periplasm, RTP Reticuloplasm, VTM Vitelline membrane, YK Yolk, YKC Yolk cells.

are first left in 80% alcohol for 24 hours and then transferred to a solution of 4% carbolic acid in 80% alcohol. Absolute alcohol should be preferably avoided for dehydration. From carbolic acid alcohol solution the material is transferred to 10 parts of carbolic acid crystals in 30 parts of benzene, changed finally into pure benzene before imbedding in wax. The best stain that clearly differentiated the protoplasm, nucleus and yolk is Carbol-Thionin recommended by Krausse (22) as particularly suitable for eggs of Coleoptera. It is prepared as follows:—1 gm. of thionin powder is dissolved in 10 cc of absolute alcohol and 90 cc of distilled water and then filtered. 20 cc of this stock solution is mixed with 5 gms. of carbolic acid crystals, 200 cc. of distilled water and 20 cc. of absolute alcohol. The time of staining varied between half an hour to one hour. After staining the sections are transferred directly to 90% alcohol, dehydrated as usual and mounted.

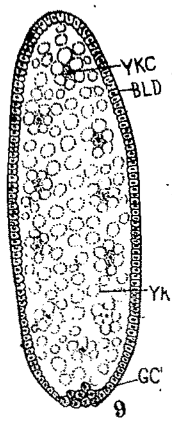
OVIPOSITION

The egg is laid in clusters of 200-230 in holes one to one and a half inches deep in loose moist soil. The beetle digs the hole with the help of its mandibles, kicking back the soil particles by the legs. The temperature at the time of egg laying is fairly high ranging between 100°-110° F and there is sufficient humidity. The pre-oviposition period is fairly long and extended up to 12 days in the laboratory. The tip of the abdomen is inserted into the hole and after laying the eggs soil particles are thrown back into the hole with the help of the legs, forming a plug covering the eggs and blocking the passage.

STRUCTURE OF THE EGG

Freshly laid eggs are white but after some time assume a pale yellow colour. Each egg is covered with a transparent sticky substance (fig. 4, ENV) which glues all the eggs together. The surface of the egg is smooth. The size of the egg increases slightly as the development proceeds.

The eggs are elongate-oval 1.38 mm long and 0.48 mm in the greatest diameter. The long axis of the egg corresponds with the future long axis of the larva. One side of the egg is slightly flattened and is the future ventral side, while the more convex side is the future dorsal side. The micropylar end which is presumptive future anterior end is tapering while the other end is broader. The egg is covered with a thin, tough, elastic and smooth chorion (fig. 1, CH) which is perforated by a deep groove the micropyle (fig. 1, MI) at the anterior end. Below the chorion is the delicate stuctureless vitelline membrane (fig. 1, VTM). At the micropylar end it appears to be attached to the chorion so that both the membranes are perforated at this point.



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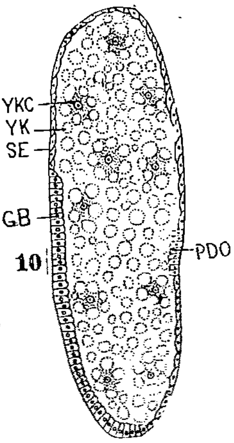

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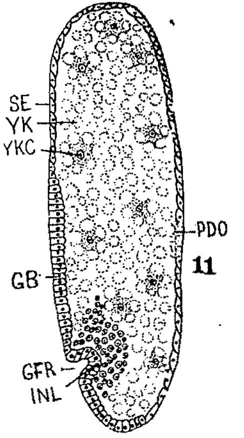

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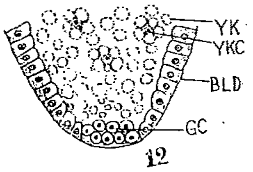

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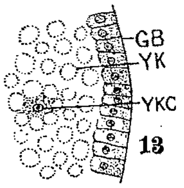

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FIG. 9. Longitudinal section of the egg showing Blastoderm formation.
FIG. 10. Germ band and primary dorsal organ formation.
FIG. 11. Formation of the gastrular furrow and proliferation of cells from the inner layer.
FIG. 12. Longitudinal section through the posterior end of the egg (blastoderm formation highly magnified).
FIG. 13. Enlarged view of a portion of the germ band.

BLD Blastoderm, GB Germ band, GC Germ cells, GFR Gastrular furrow, INL Inner layer, PDO Primary dorsal organ, SE Serosa YK Yolk, YKC Yolk cells.

Next to the vitelline membrane is a granular protoplasmic layer forming a complete envelope over the food yolk. This layer is the periplasm (fig. 1, PR). The periplasm consists of a densely arranged peripheral layer and an internal fine net-work of protoplasm. The internal layer is known as the reticulo-plasm (fig. 1, RTP)

In the net-work of the reticulo-plasm the food yolk (fig. 1, YK) is held. The elements of food yolk consist of globules of varying size with a diameter of ·024 mm.

The nucleus (fig. 1, NU) at first lies near the center at a distance of 0.08 mm from the micropyle and measures 0.036 mm in the greatest diameter. It is surrounded by a thick layer of protoplasm which is in continuation with the periplasm through the reticulo-plasm. The nucleus is large with a delicate chromatin net-work.

At the broader end of the egg lies an irregular mass of granular material partly in the periplasm and partly in the yolk. This structure is the oösome or the "germ-track determinant". (fig. 3).

MATURATION

The nucleus which lies near the center migrates towards the periphery and on entering the periplasm undergoes the maturation division, throwing off two polar bodies (fig. 2, PB). The haploid nucleus (fig. 2, NU) re-enters the reticulo-plasm and now comes to lie at a distance of 0.06 mm. behind the micropyle. The polar bodies lie at a short distance behind the anterior pole of the egg on the concave (ventral) side of egg.

FERTILIZATION AND CLEAVAGE

After the maturation division is complete the haploid egg nucleus re-enters the periplasm and gradually moves towards the micropyle. After fusion with the sperm nucleus the zygote nucleus (fig. 8, FNU) once again migrates into the reticulo-plasm. This may be observed immediately after the oviposition. On its way back it begins to undergo cleavage. The zygote nucleus becomes divided into numerous nuclear fragments (fig. 5, CNU). The majority of these nuclear fragments rapidly move to the periphery of the egg, most of them reaching the posterior end of the egg (fig. 14, CNU). These fragments enter the periplasm within 12 hours of oviposition, but some do not migrate in this way and remain behind in the yolk to form the so called vitellophags (fig. 6, YKC) within the reticulo-plasm. The nuclear fragments that enter the periplasm divide once or twice and within 24 hours after oviposition give rise to a multinucleated superficial layer of protoplasm known as cleavage cells (fig. 17, CC). The proto-

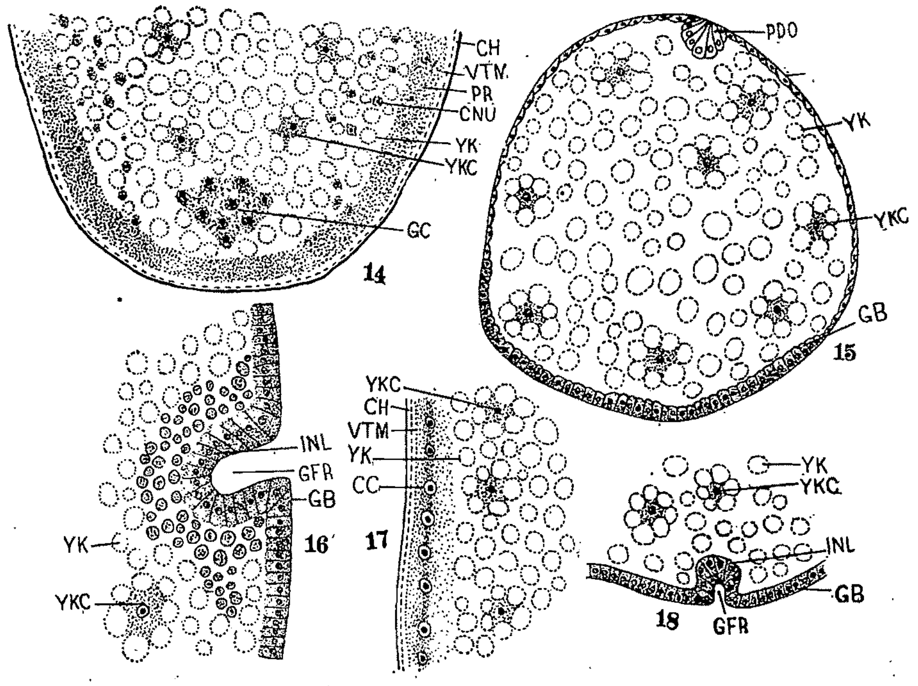

FIG. 14. Early cleavage, posterior end highly magnified., showing the breaking of oosome and the formation of germ cells.

FIG. 15. Transverse section through the anterior region of the germ band.

FIG. 16. Longitudinal section through the posterior region of the germ band showing the gastrular furrow and the cells proliferating from the inner layer.

FIG. 17. Late cleavage, formation of the cleavage cells.

FIG. 18. Transverse section through the middle region of the germ band showing the gastrular furrow without any cells proliferating from the inner layer.
CH Chorion, CC Cleavage cells; CNU Cleavage nuclei, GB Germ band, GC Germ cells, GFR Gastrular furrow, INL Inner layer, PDO Primary dorsal organ, PR Periplasm, SE Serosa, VT Vitelline membrane, YK Yolk, YKC Yolk cells.

plasm now begins to condense round the nuclear fragments and gives rise to a definite layer of cells viz. the blastoderm. The nuclear fragments which enter the oosome (fig. 5, GC) behave differently. They first become enlarged, reach the periphery and give rise to a mass of larger cells viz. the so called germ-cells (fig. 6, GC). The vitellophag nuclear fragments are surrounded by a radial mass of protoplasmic sheath. The differentiation of blastoderm cells is first perceptible peripherally immediately beneath the vitelline membrane. Gradually the constriction of the periplasm progresses until the blastoderm is composed of collumnar cells which are short. The formation of the blastoderm is complete at the end of 48 hours of incubation.

FORMATION OF THE GERM BAND

Seventy-two hours after the oviposition the formation of the germ band (fig. 10, GB) is completed on the ventral side of the egg, its anterior end extending nearly up to the middle of the egg the posterior end extending over the posterior pole of the egg. The remaining cells of the blastoderm flatten out forming the embryonic envelope the serosa (fig. 10, SE). On the opposite side of the germ band, on the dorsal side a small portion of the blastoderm becomes modified. The cells at this place become elongated and project inside the food yolk. This appears as a rudimentry germ band. It is situated more towards the anterior end of the germ band. This structure is the dorsal organ (fig. 10, PDO). In the postero ventral region of the germ band along the mid line an invagination (fig. 16, 11 GFR) takes place which is deepest in the posterior region but in the middle is not so deep (fig. 18, GFR). In the anterior part of the germ band there is no such invagination (fig. 15). This invagination is the gastrular furrow. In the posterior region where the furrow is deep the proliferation of the cells has started (fig. 7, 16) but in the middle region where the furrow is shallow there is no such proliferation of the cells (fig. 18). The portion of the germ band which has invaginated forms the inner layer (figs. 7, 18, INL).

ACKNOWLEDGMENT

I wish to thank Dr. M. S. Mani, Professor of Zoology & Entomology St. John's College Agra, for suggesting the problem, guidance and facilities for work.

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(To be continued)

ON A COLLECTION OF PLANT GALLS FROM THE CENTRAL HIMALAYAS*

By M. S. Mani, M. A., D. Sc., F. R. E. S., F. L. S., *Professor of Zoology & Entomology, School of Entomology, St. John's College, Agra.*

(With plates I-IV)

The plant galls described in this paper were collected by me in the course of two visits to the southern slopes of the lower central Himalayas during early autumn of 1952. My colleague Mr. B. L. Gupta, Professor of Botany, St. John's College, accompanied me on the first occasion. During the second visit Mr. Santokh Singh, one of my Research Associates and my other post-graduate students helped me in collecting many valuable specimens.

The southern slopes of the Himalayas are, as may be expected, extremely rich in plant galls, especially galls produced by Itonididae, but so far this region has remained unexplored. Perhaps the only galls so far known from this area are the three aphid galls (Nos. 114, 115 & 116) on *Populus ciliata* Wall., recorded by Cholodkovsky[1], one aphid gall on *Picea morinda* Lamarck (No. 122), one mite gall (No. 292), one midge gall (No. 293) and one cynipid gall (No. 294) on *Quercus incana* Roxb., included in one of my earlier papers.[2] Brief descriptions of forty-four galls, of which thirty-six are new, are given in this paper. The Itonididae account for the largest number of galls, viz. sixteen (Nos. 198, 293, 418, 423, 426, 429, 430, 432, 434, 435, 439, 441, 445, 446, 457, and 476). Some of these midge galls, especially those on *Quercus incana*, are of remarkable structure and surpass in complexity the cynipid galls on oaks. Next in order of abundance stand the mite galls, of which eleven are included here (Nos. 292, 296, 297, 419, 431, 436, 437, 443, 447, 448, and 455). Six galls (Nos. 294, 421, 433, 449,

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*Contribution No. 32 from the School of Entomology.

[1] Cholodkovsky, N. 1912. Sur quelques insectes exotiques. *Rev. russe Ent.*, **12** : 491-496, fig. 1-10.

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450 and 451) are produced by Cynipidae. Two galls are caused each by Trypetidae (Nos. 420 and 454), aphids (Nos. 422 and 444), psyllids (Nos. 81 and 427) and fungi (Nos. 425 and 428). There is one gall of Lepidoptera (No. 407) and one of Aleurodid (No. 440). It has not been possible to rear the gall makers in any of these cases, because in autumn hibernation and larval diapause had already commenced. In a few examples the gall insects had already emerged.

The photographs that illustrate this paper were taken by me with Leica, using Hektor 13.5, on Ilford HP3 and processed at 18° C in the laboratory of the School of Entomology. The microtome sections were prepared by my Research Associate Mr. Santokh Singh from material fixed in formalin. Some of the plants were identified for me by Dr. M .B. Raizada, Systematic Botanist, Forest Research Institute, Dehra Dun. The type material of the galls are in my collection.

Natural Order BERBERIDACEAE

Berberis lycium Royle

Gall No. 420 on bud by an unknown Trypetid fly

(Pl. I, fig. 7)

New gall. Regular, sessile, aggregate of 5-6 or more, globose, ovoid, indehiscent, fleshy, unilocular, thick-walled, persistent, dark brown; externally covered with imbricating scaly outgrowths representing the tips of the leaves, the bases of which have become greatly swollen and fused together. Each gall about 5 mm in diameter. Larval cavity large, oval, smooth, central and communicating to the outside by an irregularly circular apical ostiole; with a single larva or puparium. The gall tissue has 3 layers; outer layer of thick-walled dead cells in 4-5 rows; a middle layer of closely packed, simple, spongy parenchyma of uniform globose cells; and an innermost zone of empty cells lining the larval cavity and nearly as thick as the external layer of dead cells, but with the cells somewhat more closely packed. In the base of the gall irregular parenchymatous emergences project into the gall cavity from the cortex of the branch. At the seat of gall formation the branch is also conspicuously hypertrophied, especially the cortex. Near the ostiole at the apex, the gall tissue is composed largely of uniform large parenchyma cells without differentiation into the three zones. A somewhat similar gall by a midge on *Berberis darwini* and *B. empetrifolia* are described from Argentina by Trotter.[1]

Coll. M. S. Mani, Camelback Road, Mussurie Hills, 1-ix-1952.

Gall No. 425 on stem by fungus.

(Pl. I fig. 8)

New gall. Regular, globose, unilateral, solid, hard, woody, indehiscent, persistent, non-locular, solitary cortical swellings of branches, with rough dark brown bark, cracked and peeling off when old; about 20-25 mm in diameter; sometimes 2-3 galls close together, but never aggregate. The gall is largely composed of closely packed, small parenchyma cells, elongated radially and derived from the subepidermal layers of cortical tissue. An outermost layer of large dead cells surrounds a cortex of large closely packed parenchyma, the cells of which increase in size towards the interior. This is followed by a zone of moderate-sized closely packed cells. In the centre, forming a sort of medulla and constituting the great bulk of the gall are small, very closely packed elongate cells with radial groups of thick-walled wood cells. The fungal mycelia pass radially straight in the gall medulla and are intercellular, sometimes branching. The perithecia are found in the outermost zone of the gall tissue.

Coll. M. S. Mani, Camelback Road, Mussurie Hills, 2-ix-1952.

Holboellia latifolia Wall.

Gall No. 423 by an unknown midge

Irregular, extensive, tuberculated, cortical swellings of branches, 10-15 mm thick and often involving about 100 mm length of branch, multilocular, solid, parenchymatous. Epidermis broken longitudinally through by the growth of cortex. Each superficial tubercle on the gall corresponds to one larval chamber. Vascular bundles penetrate into the tubercles.

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[1] TROTTER, A. 1902. Descrizione di alcune galle dell' America del Sud. *Firenze Boll. Soc. bot. ital.*, p. 101, Nos. 4 & 5 ; HOUARD, C. 1933. Les zoocecidies des plantes de l' Amerique du sud et de l' Amerique Centrale, p. 72, Nos. 174 & 175, fig. 75-76.

Coll. M. S. Mani, on way to Barlowgunj, Mussurie Hills, 2-ix-1952.

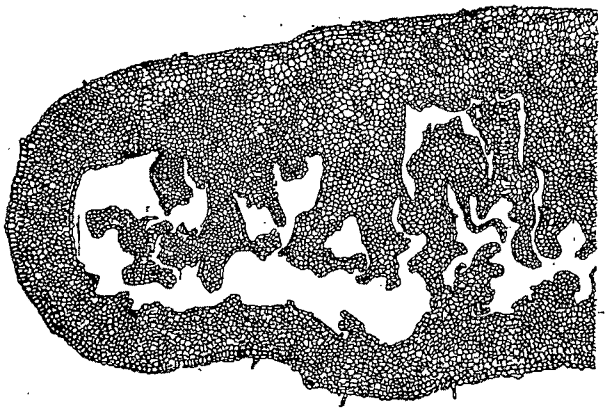
Natural Order RHAMNACEAE

Rhamnus virgata Roxb.

Gall No. 437 by *Eriophyes* sp. on leaf

New gall. Beutelgalls visible on both sides of the leaf blade, but more projecting on the lower side; hemispherical or subglobose above; obtusely conical below; about 1 mm high and 0.75 mm in diameter; ostiole circular, small hypophyllous; gall cavity with trichomes; solitary, simple, yellow to greenish-yellow, sparsely pubescent above and somewhat more below; sometimes irregular and aggregate, agglomerate or compound.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.



TEXT-FIG. 1. Part of T. S. of Gall No. 436 on stem of *Rhamnus virgata* Roxb. by *Eriophyes* sp., showing the parenchymatous emergences in the gall cavity. The entire growth is from the epidermis and the subepidermal cortical cells.

Gall No. 436 by *Eriophyes* sp. on stem

New gall. Irregular, subglobose, solitary or crowded or often agglomerate, pale yellow to greenish-yellow, tubercular emergences, about 3-4 mm in diameter, from the subepidermal layers of cortex of stem, side branches and petioles; with a minute ostiole on apex; surface finely pubescent. Gall cavity with fleshy emergences bearing sparse simple, long trichomes.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

Sageretia oppositifolia Brongn.

Gall No. 441 by an unknown midge on bud

New gall. Globose terminal bud galls, multilocular; tip of the main axis greatly swollen and bearing numerous irregularly crumpled, palmately lobed, reduced, greenish-yellow, fascicles of leafy outgrowths; gall cavities at the base of the fascicles of rosettes of leafy growths, pyriform, or irregular, spacious, often tortuous and with fleshy emergences, with a minute ostiole opening peripherally; 20-300 mm in diameter; single larva in each cavity; pupation in the gall.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

Natural Order VITACEAE

Vitis semicordata Wall.

(Pl. I, fig. 4)

Gall No. 432 by an unknown midge on branches and buds

New gall. Irregular, pyriform or subglobose, solid, hard, multilocular, brown, smooth, indehiscent, persistent, shortly pedicellate swellings of axillary buds, branches or petioles, about 20-30 mm in diameter. Larval cavities narrow, elongate and irregularly scattered in the gall tissue. Pupation in gall.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

Natural Order ANACARDIACEAE

Odina wodier Roxb.

Gall No. 198 by *Odinadiplosis odinae* Mani

(Pl. I. fig. 1)

Mani. 1934. *Rec. Indian Mus.*, **37** (4) : 435-439.

Regular, solid, globose, smooth, yellowish-green or brown, fleshy, cystiferous indehiscent galls on rachis, petioles, midribs or other chief veins. Several examples were collected by my student Mr. H. N. Baijal on the eastern slopes of Hartolla Hill, Ramgarh (Naini Tal Dt.) on 19-ix-1952. This gall is known to be widely distributed throughout India[1].

Rhus javanica Linn.

Gall No. 447 by *Eriophyes* sp. on leaf

New gall. Irregular, globose, hemispherical or tuberculated, solitary or often agglomerate, epiphyllous, hollow, fleshy, yellowish beutelgalls with the ostiole wide open, pit-like, hypophyllous; densely crowded in very large numbers, often as many as 200 over the entire surface of the leaflet; erineum moderately dense, white, simple, unbranched, sinuate, slender, unicellular, acute and rising irregularly from the lower epidermis, the cells of which are greatly hypertrophied; on the upper surface with scattered, short, recurved, erect trichomes; about 2-3 mm in diameter and about 1.5 mm high; if agglomerate often measuring up to about 5 mm across. On the lower surface of the leaf the site of gall is indicated by an irregular wide pit.

Coll. M. S. Mani, on hill side near post office, Ramgarh (Naini Tal Dt.), 6500ft., 18-ix-1952.

Natural Order LEGUMINOSAE

Indigofera dosua Ham.

Gall No. 431 by *Eriophyes* sp. on leaflets

(Pl. I, fig. 2—3)

New gall. Epiphyllous, subglobose or irregular, solitary or agglomerate, smooth or irregularly lobed, finely pubescent, reddish-brown, indehiscent, hollow beutelgalls, with hypophyllous minute ostiole; about 1-2 mm in diameter; crowded in very large numbers on almost every leaflet, with the result that the leaf as a whole is greatly deformed, curled or twisted.

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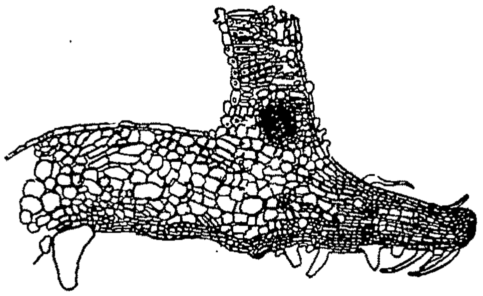
[1] MANI, M.S. 1948. *J.R. Asiatic Soc. Bengal* (Sci.) **14** (2) : 137.



TEXT-FIG. 2. Sagittal section through part of the gall near the ostiole of Gall No. 431 on leaflet of *Indigofera dosua* Ham. by *Eriophyes* sp.

Outer epidermis of gall of hypertrophied giant flattened oblong cells, produced into long, unicellular, acutely pointed trichomes, continuous with the upper epidermis of the normal part of the leaflet. Beneath this lies the undifferentiated irregular parenchyma of giant cells. Chlorophyll present in the subepidermal cells. Gall cavity large, lined by irregular, greatly hypertrophied, undifferentiated cells, often growing into the lumen as giant, blunt, unbranched, unicellular emergences, with giant nuclei. Near the hypophyllous ostiole the outer epidermis of the gall is composed of dedifferentiated cells, loaded with stellate crystals; the cells in the rim of the ostiole developed into long, unicellular simple inwardly directed trichomes. Vascular bundles of the veins irregularly scattered in the gall parenchyma.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills,3-ix-1952; various localities at Ramgarh from 6000 to 7200 ft. Coll. M. S. Mani & H. N. Baijal, 19-20. ix. 1952.

Gall No. 429 by an unknown midge on leaf

(Pl. II, fig. 2)

New gall. Regular, globose, solitary, fleshy, hollow, unilocular, indehiscent, pinkish-red, smooth, sparsely pubecent or moderately villous, sessile, thin-walled galls on rachis of leaves. The seat of gall formation is cortex. Gall cavity large, spherical, 3 mm in diameter. Larva single. Pupation in gall. Size of gall 5-7 mm in diameter.

Coll. M. S. Mani & B. L. Gupta, Chakrata Road, Mussurie Hills, 3-ix-1952; also at Ramgarh, Coll. M. S. Mani, 18-20. ix. 1952.

Gall No. 430 by an unknown midge on bud

(Pl. II, fig. 1)

New gall. Irregular, globose or pyriform, solid, indehiscent, solitary, hard, woody or fleshy, brown, smooth or often tuberculate swellings of axillary buds and branches, about 5-7 mm in diameter. Larval canals numerous, irregular. Seat of cell proliferation medulla of the branch. On the gall are often found crowded stunted leafy processes.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952; also on Hartolla hill 8000 ft. Ramgarh, (Naini Tal Dt.), Coll. M. S. Mani, 18-ix-1952.

Indigofera pulchella Roxb.

Gall No. 457 by an unknown midge on branches

(Pl. I, fig. 5)

New gall. Regular, subglobose, but usually extensive, densely deep-reddish or rusty-red hair-like fleshy elongate, straight, simple, multicellular emergences from a central core of spongy, solid, parenchymatous swollen mass, enclosing 1-2 larval cavities, which are indehiscent. The trichomes arise from subepidermal cortical cells and burst through the bark, which is then cracked and peels off or even falls off, exposing the persistent fluffy growth. Pupation in gall.

Coll. M. B. Raizada, Systematic Botanist, Indian Forest Research Institute, Chakrata Hills, 7000 ft. April, 1952.

This remarkable gall, usually mistaken for erineal growth due to attack of mites, was placed at my disposal by Dr R. N. Mathur, Systematic Entomologist, Forest Research Institute, Dehra Dun. Dr. Raizada writes in a letter that a herbarium specimen of the plant collected from Mount Abu in 1868 in the Forest Institute has the same gall.

Natural Order ROSACEAE

Prunus cerasoides D. Don.

Gall No. 422 by *Schizoneura* sp. (?) on leaf

(Pl. II, fig. 3)

New gall. Irregular, extensive, crinkling, crumpling, twisting and swelling of the entire leaf, often of several leaves of the terminal or axillary buds, to give rise to a yellow or violet coloured, tuberculated, lobulated, fleshy, hollow mass.

Coll. M. S. Mani, Camelback Road, Mussurie Hills, 1-ix-1952.

Natural Order CUCURBITACEAE

Cucumis sp.

Gall No. 454 by *Dacus cucurbitae* Coq. on stem

New gall. Irregular, extensive, fusiform, solid, fleshy, indehiscent tumescence of the branches, with irregular longitudinal larval galleries in the medulla. Pupation in soil.

Coll. H. N. Baijal, Jeolikote (Naini Tal Dt.) 18-ix-1952.

Natural Order CAPRIFOLIACEAE

Viburnum coriaceum Bl.

Gall No. 442 by midge on leaf bud

New gall. Rosette-like gall similar to No. 441 on *Sageretia oppositifolia* described above, but 40 mm in diameter and with somewhat larger and more numerous leafy outgrowths.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

Viburnum cotinifolium Don.

Gall No. 296 by *Eriophyes* sp. on leaf

(Pl. II, fig. 7)

Regular, epiphyllous, clavate or cephalonean, subcylindrical beutelgalls, somewhat curved on one side apically, yellowish-green or brown, thin-walled, about 5 mm high and 1-2 mm thick, with moderately dense, short, stiff, erect, acute trichomes on the outer surface; ostiole hypophyllous and nearly obliterated by the dense white trichomes. Gall cavity spacious, irregular, with irregular, fleshy emergences bearing stellate bundles of simple, straight or coiled, long, acute trichomes. The inner epidermis of the gall composed of giant cells. Outer epidermis moderately hypertrophied cells. Gall tissue largely of large, globose, undifferentiated closely packed parenchyma.

Coll. M. S. Mani, Vinayak hill, 6700 ft. Ramgarh, (Naini Tal Dt.), 20-ix-1952.

This gall was erroneously referred to a species of *Ficus* in an earlier paper[1].

Natural Order RUBIACEAE

Galium mollugo Linn. (=*asperifolium*)

Gall No. 434 by an unknown midge on stem

(Pl. II, fig. 4)

New gall. Regular, solitary, globose, smooth, brown, solid, fleshy, indehiscent swellings of branches about 10 mm in diameter. Larval cavities 4-5, oval, central. Surrounding the larval cavities are small-sized, regular, closely packed proliferating cells in young galls. Outside lies a thick zone of large, closely packed parenchyma cells. The epidermis of the gall is composed of irregular flattened cells; subepidermal cells likewise flattened. Vascular bundles irregularly scattered in the gall parenchyma. Seat of cell proliferation medulla of the stem, medullary rays and part of cambium.

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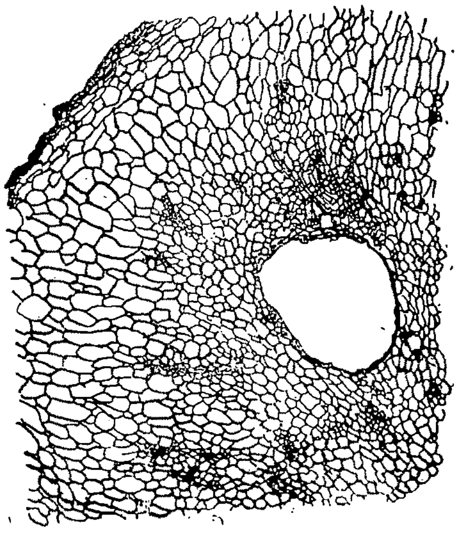
[1] MANI, M.S. 1948. *J.R. Asiatic Soc. Bengal* (Sci.), **14** (2) : 105.



TEXT-FIG. 3. T. S. through part of Gall No. 434 on stem of *Galium mollugo* Linn. by midge, showing the gall parenchyma and one larval cavity.

Coll. M. S. Mani, Chakrata road, Mussurie Hills, 3-ix-1952; also Vinayak hill, 7200 ft. Ramgarh (Naini Tal Dt.) Coll. M. S. Mani, 20-ix-1952.

Gall No. 435 by an unknown midge on bud

New gall. Irregularly subglobose, hollow, swollen leaf or flower buds, with whorls of atrophied, crumpled leafy outgrowths and enclosing several larvae. Pupation in soil.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

Natural Order COMPOSITAE

Artemisia vulgaris Linn.

Gall No. 443 by *Eriophyes* sp. on leaf

(Pl. II, fig. 6)

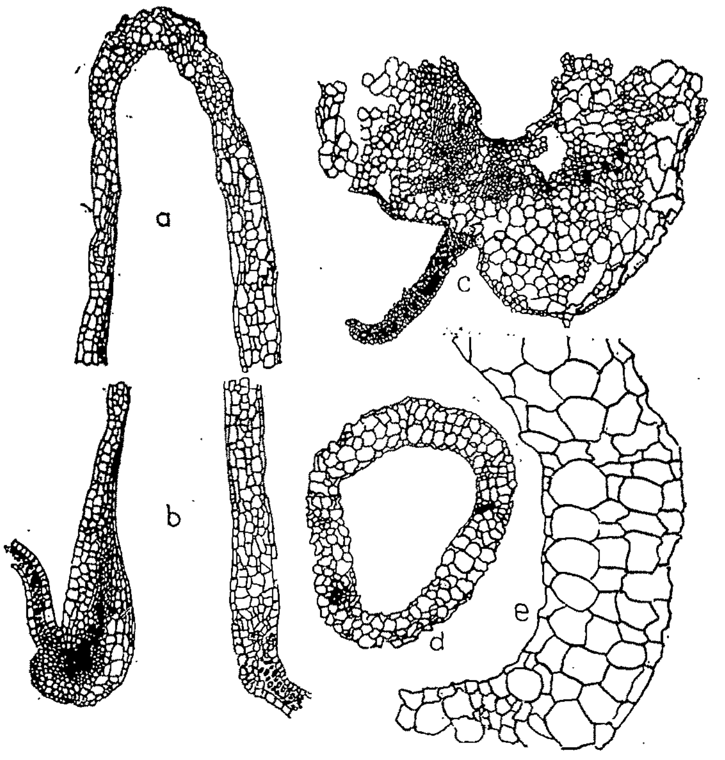
New gall. Regular, biconvex, subglobose, oval or elongate, hollow, fleshy, densely pubescent, silky-white, indehiscent beutel-galls, visible on sides of the leaf blade, about 2-3 mm in diameter as long as 7 mm and 5-6 mm wide; unilocular; ostiole hypophyllous or sometimes epiphyllous; gall cavity spacious, with fine pubescence; moderately abundant on the leaf and conspicuous on account of the silky-whiteness against the foliage green.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952; Jeolikote, 5000 ft. (Naini Tal Dt.), 17-ix-1952.

Gall No. 455 by *Eriophyes* sp. on inflorescence

(Pl. II, fig. 8)

New gall. Subglobose, solid, fleshy, indehiscent, brown or reddish, irregularly lobed and tuberculated swellings of the entire inflorescence, about 10 mm in diameter; with short scaly or leafy processes representing the reduced and malformed apices



TEXT-FIG. 4. (*a*) Sagittal section of Gall No. 427 on leaf of *Lecanthus wightii* Wedd. by Psyllid, near the apex; (*b*) the same near the base, showing the normal portion of the leaf towards the left; (*d*) T. S. of the same gall in the middle; (*e*) T. S. of a part of the wall of the same gall in the middle, more highly magnified; (*c*) A part of the T. S. of Gall No. 445 on leaf of *Artemisia vulgaris* Linn. by midge, showing the normal part of the leaf below and the larval chamber above.

of the florets; all the florets sterile, greatly swollen basally and remaining unopened; the main inflorescence axix also greatly swollen, with large, spongy parenchyma. The mites occur in large numbers in between the fleshy swollen folds of the florets. The bracts also swollen and adnate to the galled inflorescences.

Coll. M. S. Mani, Hartolla hill, Ramgarh (Naini Tal Dt.) 19-ix-1952.

Gall No. 444 by an unknown aphid on bracts and leaves.

(Pl. II, fig. 5)

New gall. Irregular, hollow, open, reddish-brown, fleshy swellings of leaf or of bract; the affected part curled or rolled up into the hollow gall and enclosing the aphids; gall cavity communicating to the outside by numerous tortuous passages; usually the apices of the affected parts remain more or less normal. The galls form in extremely very large numbers, especially on the flowering shoots, which consequently become curved and greatly contorted and stunted. Each gall measures about 7 mm in diameter.

Coll. M. S. Mani, Hartolla hill and various other localities between 7000 and 8000 ft Ramgarh (Naini Tal Dt.) 17-21. ix.1952.

Gall No. 445 by an unknown midge on leaf

(Pl. III. fig. 2)

New gall. Regular, globose, sessile, solitary or agglomerate, smooth, silky-white or with cottony appearance, fleshy, sparsely pubescent, unilocular, indehiscent, spongy galls on leaf petioles, midribs or even tender branches; 5-6 mm in diameter; agglomerate galls often as much as 10 mm in diameter. The bulk of the gall tissue (Text-fig. 4c) is composed of giant parenchyma cells, with considerable intercellular air-spaces and irregularly scattered vascular bundles. The gall epidermis rather incomplete; there is no differentiation of palisade or other tissues. The central larval cavity surrounded by a thin layer of smaller proliferating cells.

Coll. M. S. Mani, on hill slopes near Jeolikote 5500 ft. (Naini Tal Dt.), 17-ix-1952.

A somewhat similar gall is caused by the midge *Misospatha* *giraldii* Kieff. & Trott. on the buds of the same plant in China.[1]

Gall No. 407 by unknown Lepidoptera on stem

(Pl. III, fig. 1)

New gall. Subglobose, ovate or fusiform, often subterminal, hollow, unilocular, hard, woody, indehiscent, smooth but finely pubescent, local tumescence of the branches, bearing clusters of under-sized leaves; often terminally continued into a normal branch; 30 mm long and about 20 mm thick when full grown. Larval cavity in medulla. Pupation in gall.

Coll. M. S. Mani, on hill slopes near Jeolikote, 5500 ft. (Naini Tal Dt.), 17-ix-1952.

A somewhat similar gall is produced by an unknown Lepidopteran on *Artemisia herba-alba* Asso. in Algeria, Tunis and Tripoli[2].

Inula cappa DC

Gall No. 476 by an unknown midge on stem

New gall. Regular, oval or fusiform, solid, indehiscent, hard, woody, smooth, finely pubescent, multilocular diffuse swellings of terminal branches, about 10 mm in diameter and 15 mm long; larval cavities longitudinal.

Coll. M. S. Mani, on southern slopes of Hartolla hill, Ramgarh (Naini Tal Dt.), 19-ix-1952.

Natural Order ERICACEAE

Rhododendron arboreum Sm.

(Pl. III, fig. 3-4)

Gall No. 428 by *Exobasidium sp.* on leaf.

New gall. Regular, globose or oblate, strongly constricted basally and broadly and shortly peduncled; hypophyllous, solid, spongy, indehiscent, sometimes lobed but otherwise smooth and pale cottony in appearence when young and cracked and rugose, somewhat brown when old; occasionally agglomerate; usually solitary but frequently as many as a dozen on a single leaf and varying in size from that of a pea to fleshy masses over 30 mm across and 20 mm high. On the upper surface of the leaf the site of the gall is indicated by an irregular shallow discoloured concavity. The great bulk of the gall tissue is derived from the epidermis and subepidermal cells of the lower surface of the leaf and is composed of spongy, irregular giant cells, with large intercellular air-spaces; when the gall is extremely large, the palisade cells of the region are also affected and undergo both hypertrophy and cell proliferation. In the gall the peripheral zone comprises 3-4 small actively proliferating cells just beneath the outer surface, with numerous fungal hyphae (stroma) and often also on the vessels that enter the gall parenchyma from a vein at the base. The growth of the gall is confined to the extreme peripheral zone of cells only, so that it continues to increase in size enormously.

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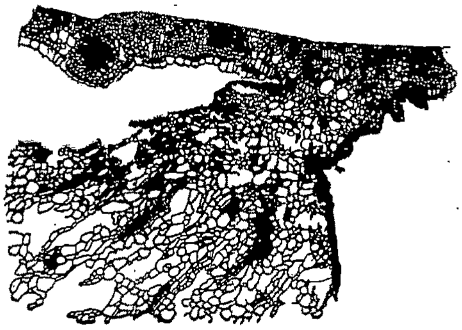
[1] HOUARD C. 1923. Les zoocecidies des plantes d'Afrique, d' Asie et d' Oceanie, 2: 882-883, No. 3194.

[2] HOUARD. C.1923. *Ibid.*, 877, No. 3172, fig. 1853-1856.



TEXT-FIG. 5. Sagittal section through the leaf and the basal part of Gall No. 428 on *Rhododendron arboreum* Sm. by *Exobasidium.* sp.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952; also in Ramgarh rarely on 19-ix-1952.

Galls on leaves of *Rhododendron indicum* Sweet by *Exobasidum discoideum* Ellis has been described from South America by Raposo.[1]

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[1] Raposo, H. 1943. A galha da azalea, *Rhododendron indicum* Sweet, provocado pelo fungo *Exobasidium discoideum* Ellis. *Bol. Soc. Brasilerira Agron.*, **6** : (1) 61-70, fig. 3.

Exobasidium rhododendri Cram. is known to give rise leaf galls on *Rh. myrtifolium* Sch. & Kotsch. in Rumania[1]. A somewhat similar gall is caused by *Exobasidium vaccini* Worn on *Rh. ferruginum* Linn. in several parts of the world[2].

Natural Order OLEACEAE

Jasminum dispermum Wall.

(Pl. IV, fig.3)

Gall No. 439 by an unknown midge on stem

New gall. Regular, local or extensive, occasionally unilateral, globose, oval or moniliform indehiscent, solid, hard, woody, smooth, brown swellings of branches, with larval cavities longitudinal and central within the medulla; cortex hypertrophied; 10 mm in diameter and 20-30 mm long.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952.

A similar gall on stem of *Jasminum* sp. is recorded to be caused by an unknown midge in Madagascar[3].

Natural Order ACANTHACEAE

Strobilanthes dalhousianus Clarke

(Pl. IV, fig. 10)

Gall No. 419 by *Eriophyes* sp. on leaf.

New gall. Mostly epiphyllous but sometimes also hypophyllous; irregularly globose or pyriform, lobed or agglomerate or tuberculate, pinkish-violet or yellowish-green, sessile beutel-galls scattered irregularly in large numbers, especially on either side of and close to the midrib; with scattered, well-separated, short, erect or somewhat curved, simple transparent trichomes. Gall cavity extensive, with numerous irregular fleshy multicellular emergences from the greatly hypertrophied epidermal cells. Ostiole wide, open; size of gall 1-2 mm in diameter. The upper epidermis of the gall hypertrophied. Beneath this is a zone of small subglobose cells with chlorophyll, with intercellular air-spaces and continuous with the pallisade cells of the normal part of the leaf and 3-4 cells deep. Within this is a zone of greatly hypertrophied, irregular spongy parenchymatous cells lacking chlorophyll but with more numerous intercellular spaces and often produced into large irregular fleshy emergences within the lumen of the gall or produced into irregular multicellular or branched hair-like outgrowths. The spongy mass of emergences are developed particularly opposite a vein and from the cortex. The inner epidermis of the gall representing the lower epidermis of the leaf is composed of enormously enlarged giant cells contributing partly to the formation of the fleshy emergences in the gall cavity. Trichomes larger than the parenchyma cells. The fleshy emergences

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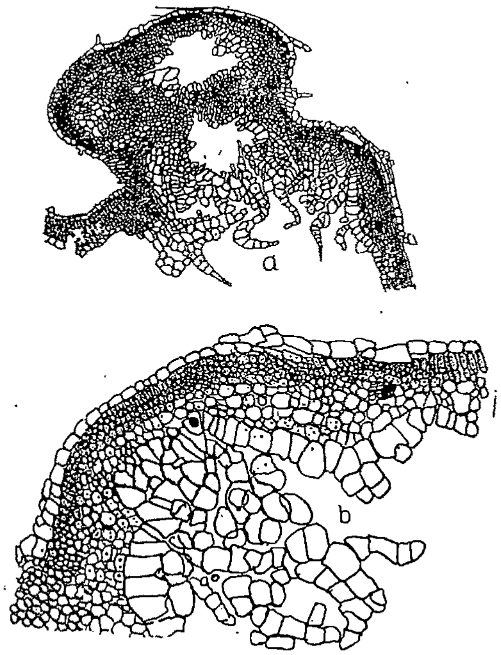
[1] Borcea, I. 1912. Deformations provoquees par *Exobasidium rhododendri* Cram. sur *Rhododendron myrtifolium* Sch. & Kotch. *Ann. Sci. Univ. Jassy*, **7** : 209-210.

[2] Zellner, J. 1913. Ueber die durch *Exobasidium vaccini* Worn auf *Rhododendron ferruginum* Linn. erzeugte Gallen. *Oest. bot. Z.*, **63**: 45.

[3] Houard, C. 1922. *Marcellia*, **19** : 39 (1920).



TEXT-FIG. 6. (*a*) Sagittal section of Gall No. 419 on leaf of *Strobilanthes dalhousianus* Clarke by *Eriophyes* sp.; (*b*) part of the gall tissues of the same gall more highly magnified to show the changes to the lower epidermis.

grow towards each other and frequently coalesce and thus divide the gall cavity into compartments.

Coll. M. S. Mani, various localities of Mussurie Hills between 1-4.ix.1952 and in Jeolikote, Ramgarh and other localities on 16-21. ix-1952.

Natural Order LAURACEAE

Phoebe lanceolata Nees

Gall No. 440 by an unknown Aleurodid on leaf

New gall. Epiphyllous, subconical, yellowish, glabrous, pit-galls on leaf, about 2 mm in diameter; ostiole wide, hypophyllous and plugged by the larva of the aleurodid, the dorsum of which is flush with the rim of the ostiole and the venter filling the gall cavity.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952; also Jeolikote near Narayani Karkana (Naini Tal Dt.) 17-ix-1952.

Natural Order MORACEAE

Ficus foveolata Wall.

(Pl. IV, fig. 4-5)

Gall No. 426 by an unknown midge on leaf

New gall. Regular, fleshy, solitary, rarely agglomerate but never compound, unilocular, yellowish, smooth, glabrous; subglobose or hemispherical on the upper surface of the leaf; bluntly truncated conical on the lower side; ostiole circular, hypophyllous, operculate; the ostiolar operculum a circular, black lid of dead cells slightly within a small crater-like depression. Larval cavity small, surrounded by a thick zone of colourless small proliferating cells. Outside of this lies a thick zone of pigmented, parenchyma of elongate, closely packed cells derived partly from the pallisade and partly from the spongy tissues of the leaf. Each gall about 2-3 mm in diameter, 4 mm high; ostiole about 1 mm in diameter. Often as many as 10-15 galls on a single leaf.

Coll. M. S. Mani, Chakrata Road, Mussurie Hills, 3-ix-1952; also in a gorge near Narayani Karkana near Jeolikote (Naini Tal Dt.) Coll. M. S. Mani & H. N. Baijal, 17-ix-1952.

Ficus roxburghii Wall.

Gall No. 81 by *Pauropsylla* sp. on leaf

Mani, 1948. *J. R. Asiatic Soc. Bengal* (Sci.), **14** (2) : 117.

Regular, subglobose or pyriform, solitary but also agglomerate or compound, hollow, thick-walled, fleshy, dehiscent, smooth, glabrous, greenish or yellowish beutelgalls, but visible on both sides of the blade, though largely hypophyllous; ostiole hypophyllous and nearly obliterated. About 10-12 mm in diameter.

Coll. M. S. Mani, Jeolikote, 16-ix-1952.

Natural Order URTICACEAE

Boehmeria platyphylla Don.

Gall No. 446 by an unknown midge on leaf

(Pl. IV, fig. 9)

New gall. Regular, globose, free, reddish-brown, smooth beutelgalls with well separated long, erect, white unbranched straight trichomes; 5 mm in diameter; visible equally on both sides of the leaf blade; up to about 10 on a single leaf and usually close to one of the larger veins; hollow, unilocular, indehiscent. Gall cavity large, globose, central, smooth with a single larva.

Coll. M. S. Mani, near Narayani Karkana near Jeolikote (Naini Tal Dt.), 17-ix-1952.

This gall is entirely different from a much smaller pustule-like midge gall on the leaf of the same plant described from the Camerouns[1].

---

[1] HOUARD, C. 1923. Les zoocecidies des plantes d' Afrique, d' Asie et d'Oceanie, 1 : 206 No. 769.

Lecanthus wightii Wedd.

Gall No. 427 by an unknown Psyllid on leaf

(Pl. IV, fig. 1-2)

New gall. Regular, hollow, membranous, succulent, conical, horn-shaped beutelgalls with wide open hypophyllous ostiole, white smooth, glabrous, about 10-15 mm high and 1.5 -3 mm thick basally; apically obtusely rounded; never more than 3-4 on a leaf and always free and solitary. Outer epidermis of gall of simple hypertrophied flat cells without stomata and continuous with the upper epidermis of the normal part of the leaf. Beneath this lies a mass of closely packed, irregular parenchyma of giant cells, 4-5 deep (Text-fig. 4). The inner epidermis of the gall incomplete. A few vascular bundles in the gall parenchyma entering from the veins. The transition from the normal to the gall tissue is abrupt at the base of the gall, where the leaf blade is suddenly and deeply invaginated upwards. A single nymph of the psyllid in each gall. Most of the galls collected were empty.

Coll. M. S. Mani, various localities in Mussurie Hills, 3-ix-1952.

Natural Order JUGLANDACEAE

Juglans regia Linn.

Gall No. 297 by *Eriophyes* sp. on leaf

New gall. Regular, biconvex, solid, indehiscent smooth, circular beutelgalls, equally developed on both sides of the leaf blade, about 2 mm in diameter and about 1.5 mm thick; unilocular, ostiole hypophyllous or epiphyllous; rusty-brown; irregularly scattered in large numbers on leaves; gall cavity filled with dense short, brown fleshy emergences.

Coll. H. N. Baijal, PWD Rest House, 6200 ft Ramgarh (Naini Tal Dt.) 18-ix-1952. I have also specimens of this gall on leaf and on fruits from Paghman (Kabul), 7300 ft. Afghanistan, Coll. Dr. Taskhir Ahmad, 29-vi-1939.

Natural Order SALICACEAE

Salix daphnoides Willars

Gall No. 418 by an unknown midge on leaf

(Pl. I, fig. 5)

New gall. Regular, solid, indehiscent, hard, unilocular, epi- or hypophyllous, free, agglomerate or compound beutelgalls, with the ostiole obliterated except for a conspicuous circular shallow crater-like hypophyllous depression on the gall. The galls are crowded in very large numbers on either side and on the midrib, which is usually more or less greatly intumescent and curved. Larval cavity small, elongate oval. Each gall cavity may contain 2-3 larvae. Each gall measures about 7-10 mm in diameter; reddish-yellow or reddish-brown.

Coll. M. S. Mani, Camelback Road, Mussurie Hills, 1-ix-1952.

Natural Order FAGACEAE

Quercus dilatata Lindl.

Gall No. 448 by *Eriophyes* sp. on leaf

New gall. Mostly epiphyllous, regular, hemispherical circular, blister-like beutelgalls, about 4 mm in diameter, yellowish-green, smooth, glabrous, with wide open cavity hypophyllous covered by dense erineum of long, brown, curled, simple hairs.

Coll. M. S. Mani, Vinayak hill, 7200 ft. Ramgarh (Naini Tal Dt.), 20-ix-1952.

Gall No. 451 by an unknown Cynipid on leaf

New gall. Regular, globose, hypophyllous, pinkish-brown, smooth, glabrous, sessile, indehiscent, unilocular galls placed near the midrib; sometimes epiphyllous; larval cavity large, with 1-2 pupae of the cynipid. Pigmented parenchyma cells surround the central zone of unpigmented small proliferating cells. Size of gall 3-3·5 mm in diameter. The gall readily breaks off by the slightest touch, leaving a scarcely visible scar.

Coll. M. S. Mani, Vinayak hills, Ramgarh (Naini Tal Dt.) 7200 ft. 20-ix-1952.

Gall No. 450 by an unknown cynipid on leaf

(Pl. IV, fig. 6)

New gall. Regular, subglobose, ovoid or hemispherical, solid, multilocular, hard, indehiscent, sessile, smooth, glabrous, slaty-grey persistent of swellings leaf blade about 10-13 mm in diameter and 9 mm thick, usually conspicuously gibbous on one side of the blade. Larval chambers crowded, oval, arranged radially in the peripheral mass of the gall and usually communicating into a large central chamber; with numerous circular exit holes in the old galls. The great bulk of the gall is parenchyma of elongate cells with pigment. The larval cavities are lined by smaller unpigmented proliferating cells.

Quercus incana Roxb.

Gall No. 292 by *Eriophyes* sp. on leaf

Mani. 1948. *J. R. Asiatic Soc. Bengal* (Sci.) **14** (2) : 106, fig. 35.

Epiphyllous, regular, solitary, hemispherical pustule-like beutelgalls, about 5 mm in diameter, up to about 20 per leaf, yellowish-green, smooth, glabrous above and below with rusty brown erineum.

Coll. M. S. Mani, various localities in Ramgarh, 19-ix-1952.

Gall No. 293 by an unknown midge on leaf

(Pl. III, fig. 6-7)

Mani. 1948. *J. R. Asiatic Soc. Bengal* (Sci.), **14** (2) : 152, fig. 24.

Mostly hypophyllous, very rarely epiphyllous, regular, free, never agglomerate, elongate-oval, mango-fruit-shaped, pedicellate, somewhat laterally compressed, uni- or bilocular, hard woody, thick-walled, indehiscent, deciduous, brownish-green, densely tomentose beutelgalls on leaves, somewhat bluntly produced

into a conical curved beak apically. On the opposite side of the leaf the site of the gall is indicated by a short, solid, hard subtruncate tubercle. Gall about 15 mm long, 8 mm broad and 5 mm thick. Up to about a dozen galls form on a single leaf. Trichomes in stellate bundles. Larval cavity with very hard, brittle cyst, surrounded by proliferating cells. Outside this lies the gall parenchyma. Larvae 1-2 in each gall. Pupation in gall.

Coll. M. S. Mani various localities in Ramgarh, 18-ix-1952.

Gall No. 449 by an unknown cynipid on leaf

(Pl. IV, fig. 8)

New gall. Epiphyllous or hypophyllous, regular, solitary, subglobose, sessile, deciduous, pinkish-brown, smooth or with one or two obscure mucronate tubercles, glabrous, indehiscent, about 5 mm in diameter and situated on the side of the midrib; unilocular; gall cavity central large, with a thick zone of colourless proliferating cells, surrounded by the pigmented parenchyma.

Coll. M. S. Mani, various localities in Ramgarh, 19-20. ix.1952.

Gall No. 433 by an unknown cynipid on leaf

(Pl. III, fig. 8-9)

New gall. Regular, globose or oval, sessile, unilocular, hollow, free, simple, indehiscent, hypophyllous, smooth, glabrous, pale reddish-brown galls crowded in close series on the midrib on either side, with exit holes, 1-2 on each gall ; 5 mm long and 2 mm thick.

Coll. M. S. Mani, Chakrata Road, Musssurie Hills, 3-ix-1952.

Gall No. 294 by an unknown cynipid on stem.

Mani. 1948. *J. R. Asiatic Soc. Bengal* (Sci.), **14** (2) : 156, fig. 36.

Irregular, local or extensive, solid, woody, globose, oval or subfusiform indehiscent, multilocular persistent cortical swellings of branches, with smooth surface; about 15-20 mm thick; with larval cavities of hard cells; exit holes numerous and circular.

Coll. R. D. Saksena, Kumaon, June 1942.

Gall No. 421 by an unknown cynipid on bud

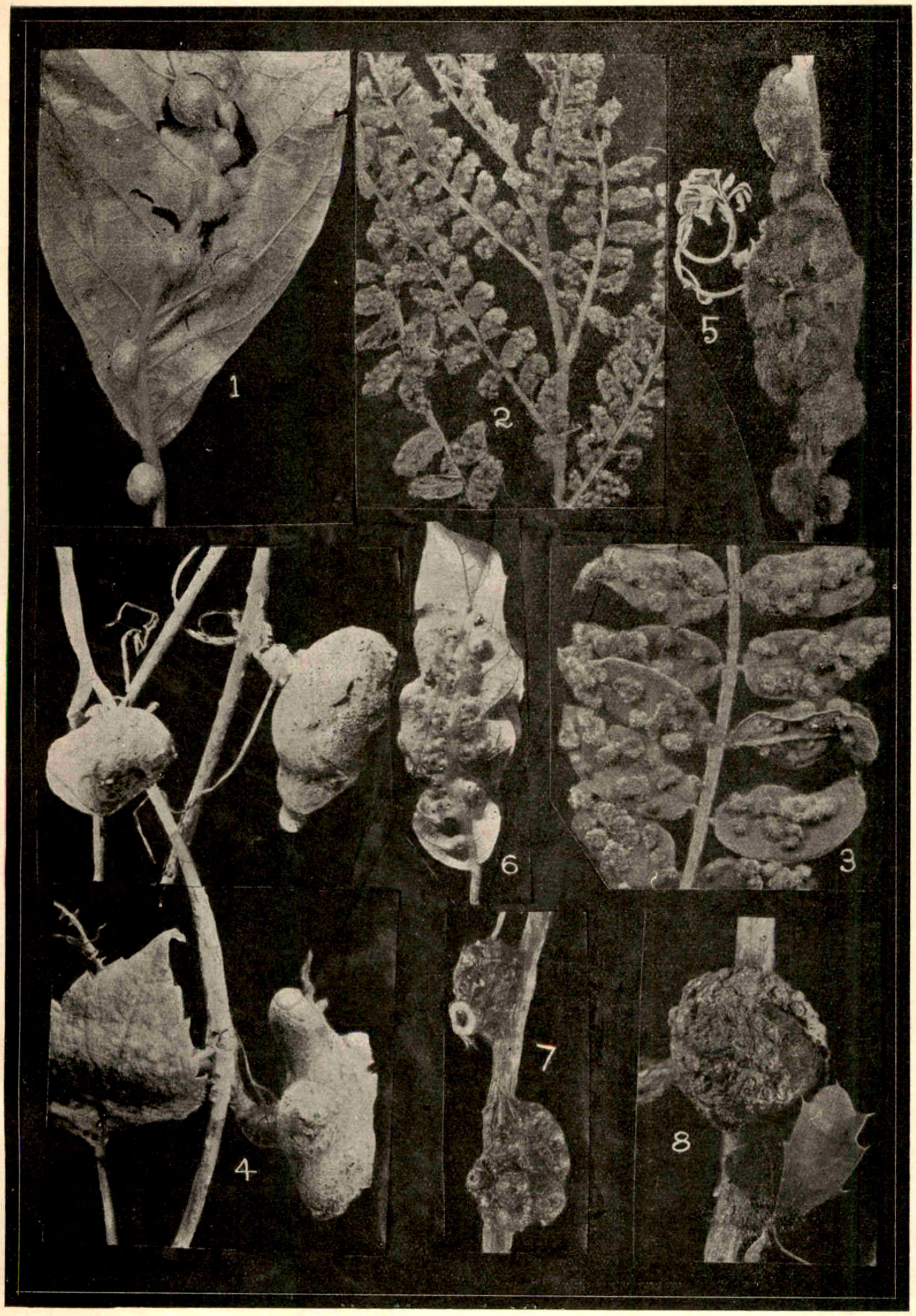
(Pl. IV, fig. 7)

New gall. Irregular, globose, oval or pyriform solid, indehiscent, multilocular, hard, rugose, dark reddish-brown, compound galls on buds, about 25-30 mm in diameter.

Coll. M. S. Mani, Camelback Road, Mussurie Hills, 1-ix-1952; also Hartolla hill, Ramgarh, 19-ix-1952.

PLATE I.

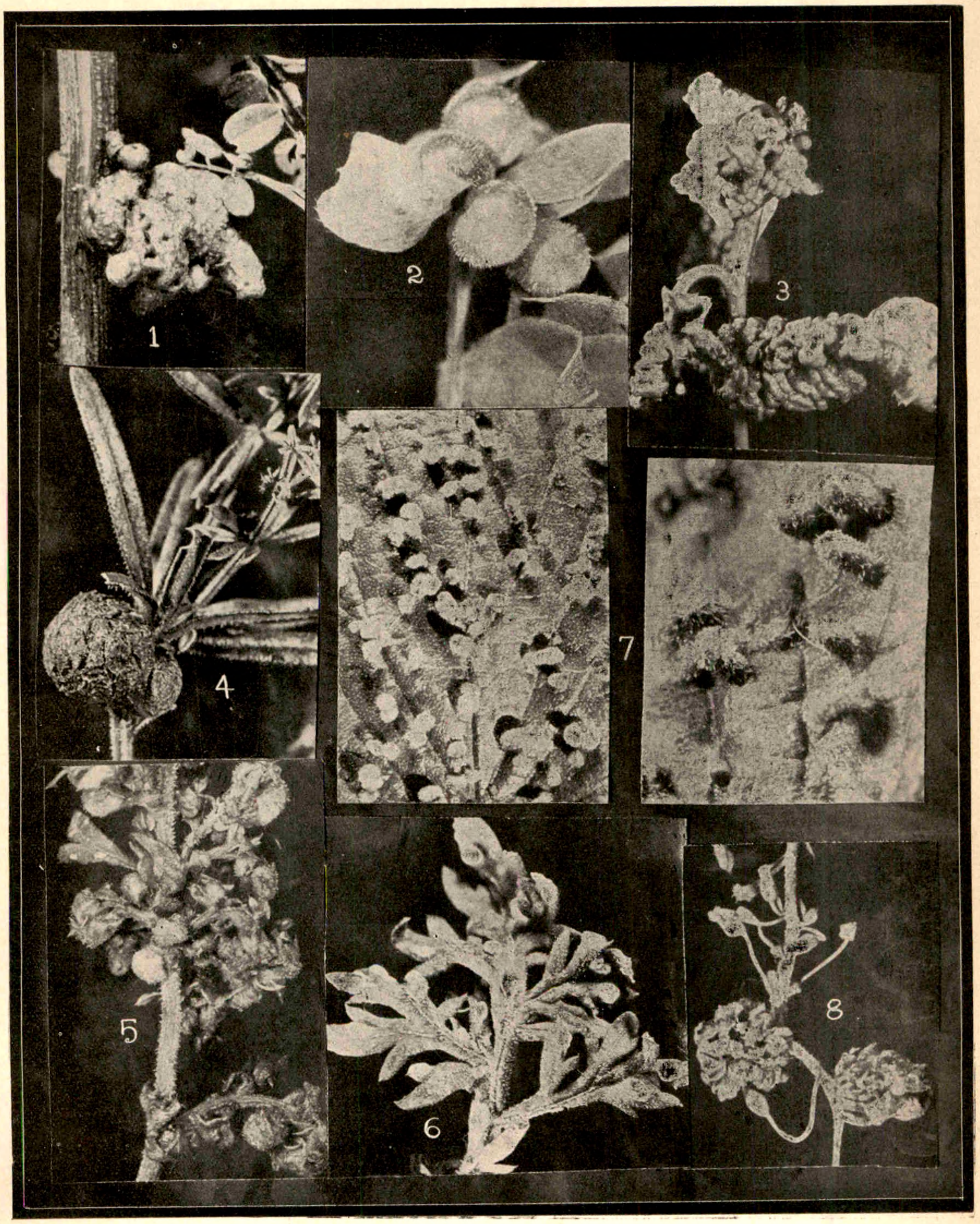
FIG. 1. Gall No. 498 on *Odina wodier* Roxb. by *Odinadiplssis odinae* Mani.
FIG. 2-3. Gall No. 431 on *Indigofera dosua* Ham. by *Eriophyes* sp.
FIG. 4. Gall No. 432 on *Vitis semicordata* Wall. by an unknown midge.
FIG. 5. Gall No. 457 on *Indigofera pulchella* Roxb. by an unknown midge.
FIG. 6. Gall No. 418 on *Salix daphnoides* Willars by an unknown midge.
FIG. 7. Gall No. 420 on *Berberis lycium* Royle by an unknown trypetid fly.
FIG. 8. Gall No. 425 on *Berberis lycium* Royle by an unknown fungus.



M. S. Mani : Plant Galls

PLATE II.

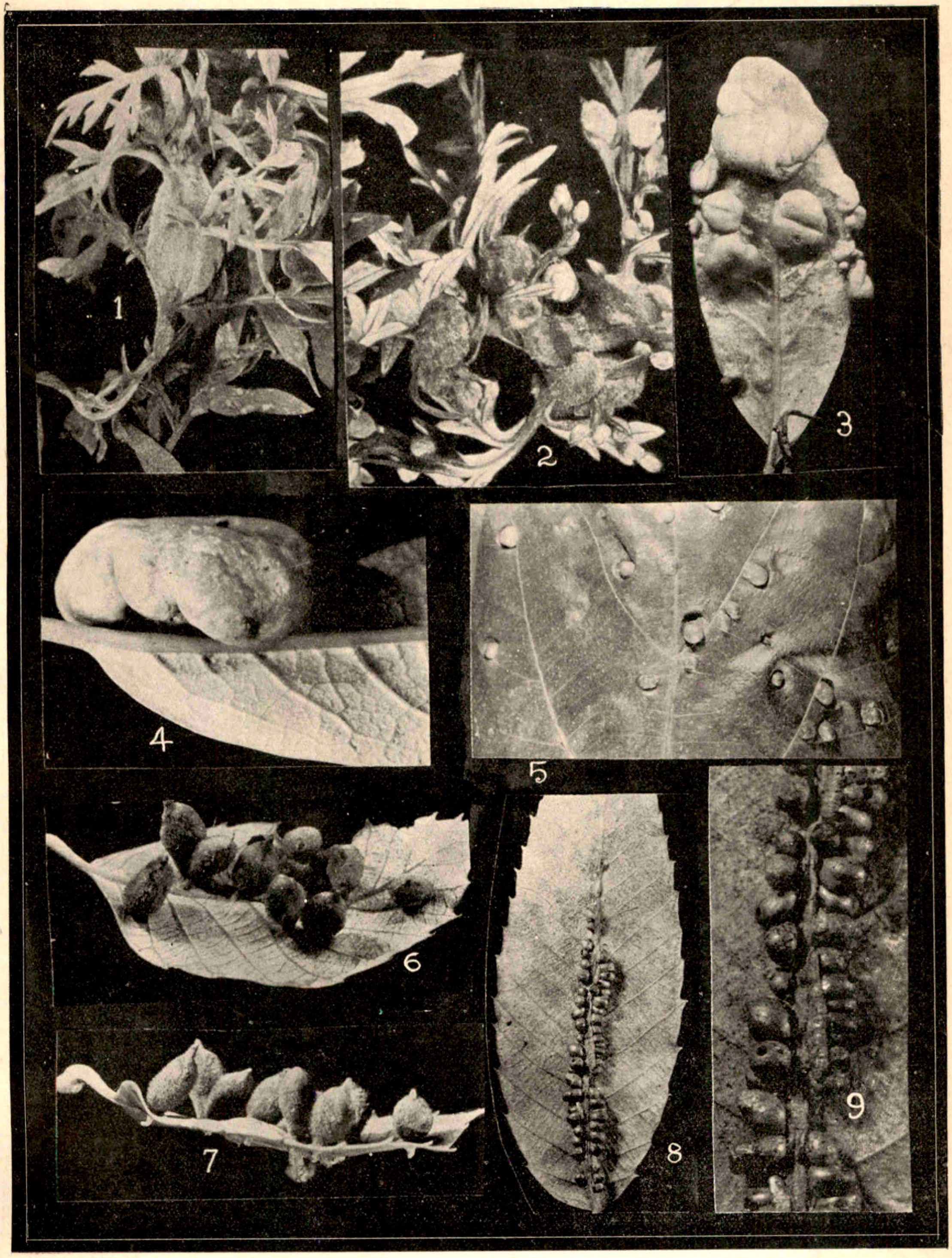
FIG. 1. Gall No. 430 on *Indigofera dosua* Ham. by an unknown midge.
FIG. 2. Gall No. 429 on *Indigofera dosua* Ham. by an unknown midge.
FIG. 3. Gall No. 422 on *Prunus cerasoides* D. Don by *Schizoneura* sp.
FIG. 4. Gall No. 434 on *Galium mollugo* Linn. by an unknown midge.
FIG. 5. Gall No. 444 on *Artemisia vulgaris* Linn. by an aphid.
FIG. 6. Gall No. 443 on *Artemisia vulgaris* Linn. by *Eriophyes* sp.
FIG. 7. Gall No. 296 on *Viburnum cotinifolium* Don. by *Eriophyes* sp.
FIG. 8. Gall No. 455 on *Artemisia vulgaris* Linn. by *Eriophyes* sp.



M. S. Mani : Plant Galls

PLATE III.

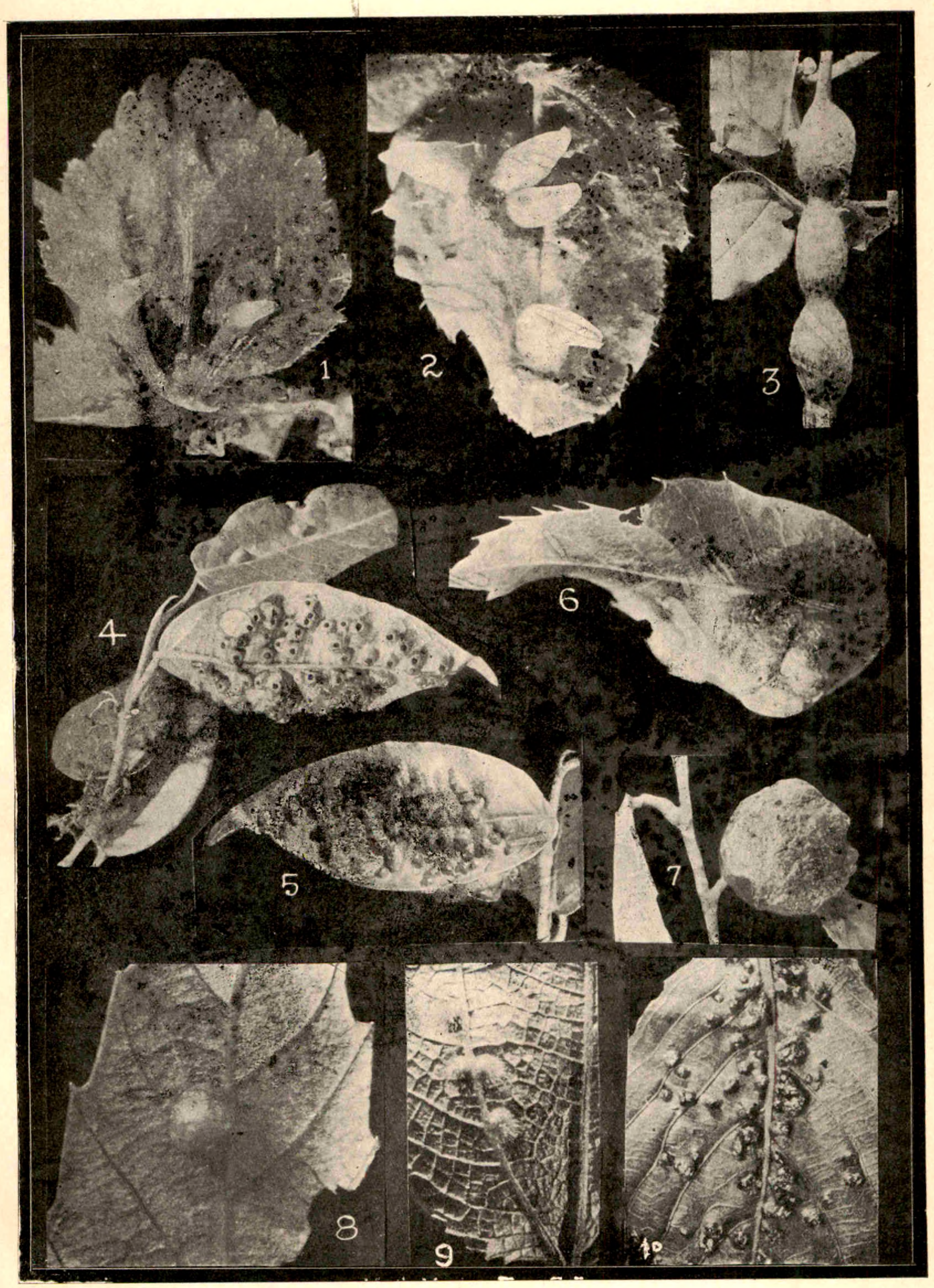
FIG. 1. Gall No. 407 on *Artemisia vulgaris* Linn. by an unknown lepidopteran.
FIG. 2. Gall No. 445 on *Artemisia vulgaris* Linn. by an unknown midge.
FIG. 3. Gall No. 428 on *Rhododendron arboreum* Sm. by *Exobasidium* sp.
FIG. 4. Gall No. 428 on *Rhododendron arboreum* Sm. by *Exobasidium* sp.
FIG. 5. Gall No. 81 on *Ficus roxurghii* Wall. by *Pauropsylla* sp.
FIG. 6-7. Gall No. 293 on *Quercus incana* Roxb. by an unknown midge.
FIG. 8-9. Gall No. 433 on *Quercus incana* Roxb. by an unknown cynipid.



M. S. Mani : Plant Galls

Plate IV.

Fig. 1-2. Gall No. 427 on *Lecanthus wightii* Wedd. by an unknown psyllid.
Fig. 3. Gall No. 439 on *Jasminum dispermum* Wall. by an unknown midge.
Fig. 4-5. Gall No. 426 on *Ficus foveolata* Wall. by an unknown midge.
Fig. 6. Gall No. 450 on *Quercus dilatata* Lindl. by an unknown cynipid.
Fig. 7. Gall No. 421 on *Quercus incana* Roxb. by an unknown cynipid.
Fig. 8. Gall No. 449 on *Quercus incana* Roxb. by an unknown cynipid.
Fig. 9. Gall No. 446 on *Boehmeria platyphylla* Don. by an unknwon midge.
Fig. 10. Gall No. 419 on *Strobilanthes dalhousianus* Clarke by *Eriophyes* sp.



M. S. Mani : Plant Galls

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RESONANCE STRUCTURE AND PARACHOR

PART I.—RESONANCE AND PARACHOR

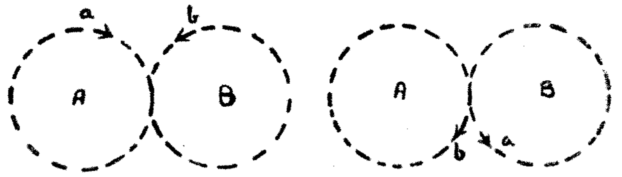
By W. V. BHAGWAT AND R. P. SHUKLA, *Department of Chemistry, Holkar College, Indore.*

INTRODUCTION

Various properties, such as dipole moment, molecular spectra, bond distance, resonance energy, etc., have been used to elucidate the problem of resonance structure of molecules. No work seems however to have been done concerning the relation between the parachor and resonance. Glasstone (12) has mentioned that apparently the resonance effect does not influence the parachor of benzene, since the experimental value 206.2 corresponds to the calculated value 207.1 for Kekule structure (25). It is not known on what grounds Sudgen (25) expected a difference between the calculated and the observed values. The idea of resonance structure of molecules is recent as compared to parachor and it may be due to this fact, that this property remained unrelated to resonance, although it had been applied successfully in practically all fields to elucidate molecular structure. An attempt is made by us in this paper to show the relation between the resonance and parachor. Two short notes have already been published by us on this subject (3).

RESONANCE STRUCTURE AND PARACHOR

The theory of resonance requires that the potential energy of the combination of various possibilities should have a solution with minimum potential energy, so as to give stability to the molecule. The energy excess gives an idea of resonance energy. Consider the case of a hydrogen molecule. A hydrogen molecule may be considered to consist of two protons 'A' and 'B' and two electrons 'a' and 'b'. The two configurations Aa, Bb and Ab, Ba are possible. Each of these configurations is considered to represent two isolated states. If two atoms Aa and Bb are brought nearer together, a time will come when they are sufficiently closed for each electron effectively to feel the force of both nuclei and of other electron. A new situation of equilibrium then becomes possible.



In other words resonance stabilisation occurs and from quantum mechanics it is clear that the elctrons pass more time in the region between the nuclei. It follows from above, that in all cases of resonance the interchangeable electron should pass more time in the vicinity of the nuclei, for then alone the potential energy of the molecule tends to contract, so as to have minimum potential energy. Thus the molecular volume or the parachor (the molecular volume when the surface tension is unity) tends to fall. Obviously only such resonating structures will be possible as will have the parachor values not very different from one another, since the theory of resonance requires that various structures should not have much variation in their potential energies. It is thus possible to connect the parachor with resonance and enunciate the parachor conditions for resonance.

The various electronic configurations should have the same or practically the same parachor, with a tendency to decrease it slightly. Here it is necessary to discuss the extent of this decrease in parachor. It may be due to two causes:— (*a*) interchangeable electrons passing more time in the region between two nuclei; (*b*) the molecules being polar. In this case there is contraction on account of internal attraction. Sugden (27) has observed a decrease of 1.6 units for semi-polar bond. This value is questioned by Subnis and Bhagwat (2). It is clear however that the polar nature of the molecule tends to decrease the parachor. Since this decrease cannot be assumed to be identical in all polar structures, it is not correct to assume a constant value for it. We have therefore discussed the term 'contraction' in general. The first cause is not supposed to have any appreciable effect, but there is a possibility of greater decrease due to the second cause.

If a number of electronic configurations are possible, those which show a larger deviation in parachor will have smaller contribution towards resonance.

If a number of unstable configurations are possible with same parachor, then it is possible for them to contribute towards resonance with stable configurations, since on quantum mechanical basis they can attain some sort of stability.

APPLICATION OF PARACHOR TO RESONANCE

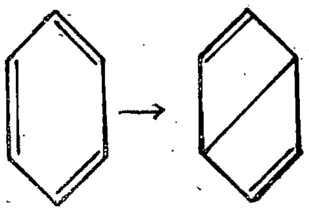
Sugden (28) has given the values of atomic and structural parachors.

H=17.1	Triple Bond	46.6
C=4.8	Double Bond	23.2
N=12.5	Six membered ring	6.1
O=20.5	Four membered ring	11.6

These results apparently indicate nothing, but on closer examination we observe two important things viz. (*a*) The parachor of a triple bond is twice that of a double bond. (*b*) The parachor of a double bond is twice that of a four membered ring. These relations are not accidental. In conjunction with the parachor theory of resonance they tell us how the resonance is going to occur. We will take the first significant observation and discuss its method of application.

We know that, the parachor of a triple bond is equal to twice the parachor of a double bond plus the parachor of a single bond. It is zero or 46.6=2x23. 2 0. In other words, if the structure of a molecule so changes that the two double bounds in a molecule disappear and a new structure containing a triple bound and a single bond in its place appears, there will be no change in parachor. Such a change therefore satisfies the parachor condition (i) for resonance. Secondly, when a double bond changes to a triple bond, the bond distance falls and hence there is a tendency to contract. Obviously the actual possibility depends on whether the value of bond distance of single bond between the concerned atom plus the bond distance of the triple bond is smaller than twice the bond distance of the double bond. Normally the variation in parachor due to such a change will be very small. Thus the existence of two alternative structures $=A=$ and $\equiv A-$ becomes possible. It will be clear therefore that the observation that the parachor of a triple bond is double that of a double bond is not accidental, but is due to the possibility of resonance. Had this significance been realised earlier, parachor would have given a lead to the theory of resonance.

The discussion of second significant observation is similar. If a structure containing a double bond changes in such a way that, a double bond disappears and two rings of four appear, there will be no change in parachor and hence the resonance between such alternative structures is possible.

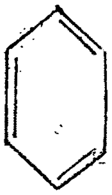


In addition to the above two ways of keeping parachor practically constant, there is a third way, in which the total number of bonds of various types remain the same, but their places in the molecule are exchanged. $C=A-B$ and $C-A=B$. The resonance between such structures therefore can occur. Thus the parachor theory of resonance predicts three types of possibilities by which occurrence of resonance can be predicted. We will consider them in the following order :—

(1) Resonance structures in which there is only exchange of places by the bonds of different types.

$C{=}A{-}B$ and $C{-}A{=}B$

(2) Resonance structures in which a double bond changes into two rings of four.



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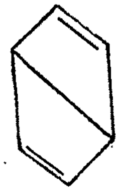


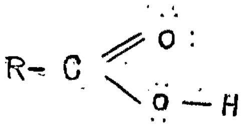
(3) Resonance structures in which two double bonds change into a triple bond and a single bond,

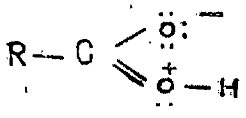
$${=}A{=} \text{ and } {\equiv}A{-} \text{ or } {-}A{\equiv}$$

(A) RESONANCE STRUCTURES IN WHICH BONDS EXCHANGE POSITIONS

The simplest cases of resonances, which can be explained by our 'parachor theory' are those in which the total number of linkages of various types remain the same and thus the parachors remain practically identical. The only change is the shifting of bonds from one atom to another. The following examples will illustrate the method of applying parachor theory of resonance in such cases.

The Carboylic acids.—The carboxylic acids may have the resonating structures.

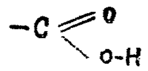




This is confirmed by the work of L. Pauling and L. O. Brockway,(21) W. H. Zachariasen(32), G. Albrecht and R. B. Corey, (23) and J. M. Robertson (12).

According to our parachor theory of resonance, a double bond and a single bond between two oxygen atoms have only exchanged places and hence as there is no change in parachor, the resonance between the two structures is possible. Obviously the parachors of the two structures are not identical, since the two resonating structures are not equivalent due to the distribution of electric charge on the latter. There is a possibility of lowering the parachor further on account of this polar structure as has been discussed previously.

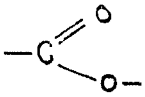
The calculated value of parachor for



while the observed value in alphatic acid is approximately 75. This enchanced lowering must be due partly to the polar nature of the resonating structures. However, the problem is complicated due to the formation of dimers, (21) by these acids and the large decrease may be due to hydrogen bonding. This point will be discussed separately.

The resonance structures of carboxylic esters are similar and hence they are possible according to our theory.

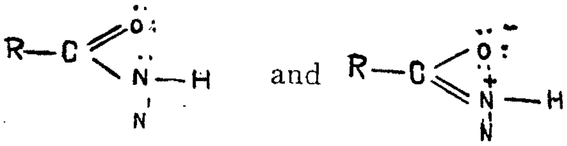
The calculated value for the parachor of



group is 68 while the observed value from the parachors of aliphatic esters is 66. The observed lowering may be attributed to resonance and the existence of polar structure may be regarded as the main cause for this decrease in the parachors.

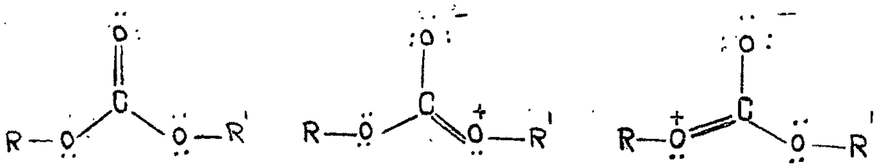
The case of carboxyl-ion is similar. Here again the bonds are exchanged between the two oxygen atoms and hence the two structures have the same parachor. The resonance therefore becomes possible and is complete unlike esters and acids, because the two structures in case of carboxylious are equivalent. Our parachor theory of resonance also explains the resonanting structures of glycine (14).

The parachor of acetamide (26) is 148, while the calculated value is about 151. The decrease can be explained on the basis of the two resonating structures which have pratically the same parachor. The polar structure lowers the parachor due to internal attraction and the consequent contraction in volume. Amides in general therefore may have the resonating structures.



The resonance energy of these structures does not lead to any significant conclusion, and there exist no data concerning the configuration and dimension of the amide group. However, our parachor theory and the parachor data on acetamide support the existence of the resonating structures. Discussion of H-bonding in amides will be taken seperately.

The parachor of diethyl carbonate (15) is 274·9, while the calculated value is 278·1 This decrease may be attributed to the resonance between the three possible structures. In general the carbonates may be represented by the configurations.



Due to polar nature of the latter two structures, the molar volume or parachor is likely to be diminished still further due to internal attraction. This is the cause of the lower value for the parachor of diethyl carbonate. Parachor theory of resonance therefore clearly explains the existence of the above three resonating structures. According to this theory the resonance is possible, because there is only exchange of places by the single and double bonds and apparently there is no change in parachor. However the polar nature causes the lowering. X-ray study of Calcite (14) is in agreement with these structures.

Pauling (19) suggests an additional structure, for carbonates. This will cause a parachor decrease of 23·3 units, since one double bond has disappeared. The extent of contribution by this structure has not been stated. This structure is not possibe according to parachor theory of resonance. The result of parachor of diethyl carbonate also does not support it. It may be therefore concluded that the contribution, if any, by structure is negligible.

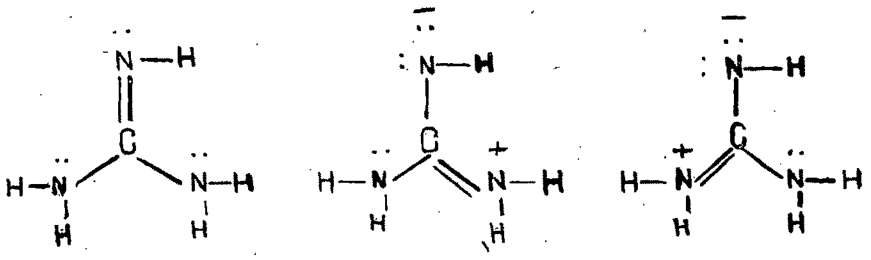
Similar resonating structures will be possible for carbonate ion, since they have the same parachor. All these structures will however, be equivalent unlike the structures of alkyl carbonates. This is supported by electron diffraction results. The three C–O distances are found to be identical and correspond to C=O value (1·23 A observed) (4,7).

Parachor of NO_3 group in ethyl nitrate (26) comes out to be 94·5. This is very near to the calculated value 95·7 obtained for the resonating structures.

In these structures there is only an exchange of positions by the single and double bonds. Hence there is apparently no change in parachor and the resonance between these three structures becomes possible. All these structures are equivalent. A slight lowering in parachor value due to polar structures is expected. This is supported by the parachor results of ethyl nitrate. Electron diffraction results support this view, since all N—O distances are found to be equal and correspond to the double bond structure N=O (1·13 A° observed). (7)

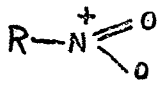
The observed value of interatomic distances for urea (31) are C—O = 1.25 A° and C—N = 1.37 A°. This indicates 60% double bond character for C—O linkage and 20% for C—N linkage. Parachor theory of resonance supports the possibilities of its three resonance structures, since they have practically the same parachor.

Reliable data for the interatomic distances of guanidine are not available, but on the same lines as these of urea, it can be stated to have the following possible structures:—

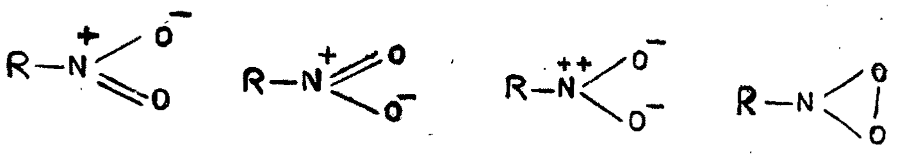


Again there is a simple exchange of places by the bonds involved and hence there is no apparent change in parachor. Thus the parachor theory suggests the possibility of resonance between these structures.

According to electronic theory of valency, the structure of nitro group is represented as

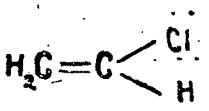


This type of structure suggests dissymentry. However, dipole moment observations (13) and electron diffraction results (24) support symmetrical structures. The work of James King and Horrocks (16) on electron diffraction para-di-nitrobenzene does not support Pauling's view. Nitro group can have the following structures:-



According to parachor theory, the resonance between these four structures is not possible, since in case of structure (III) there will be a parachor decrease of 23.2 units, as a double bond has vanished, while in the case of structure (IV) a double bond is replaced by a ring of three, thus causing a total decrease of 6-5 units in the Parachor. The observed parachor of nitro groud is 73.1, while that calculated for structures (I) and (II), is 74.1. Parachor results therefore support the resonance between structures (I) and (II), because they have practically the same parachor. Pauling suggests that perhaps there is a small contribution from the structure (III). Our parachor theory of resonance does not support this view. The observed value of parachor for nitro group is against it. It will be clear that the parachor theory lends support to dipole moment view and electron diffraction view of Pauling which was contradicted by the work of James, King and Horrock. (17).

Chloro-ethylenes.—The chemical properties of chloro-ethylenes differ strikingly from those of the saturated aliphatic chlorine compounds. It is suggested that they have resonating structures (20) of the types:—



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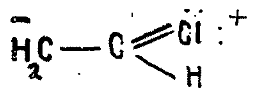
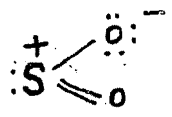
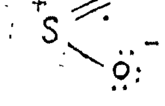


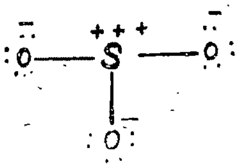
The two structures differ only in the places occupied by the double and the single bond. This causes no change in parachor and hence according to our theory, resonance between these structures is possible.

Sulphur dioxide.—According to electronic theory of valency, sulphur dioxide is represented as :—



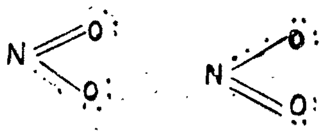
This is not supported by the measurement of the parachor of sulphur dioxide. The calculated value 111.5 does not agree well with the experimental 28 value 101.4. The electron diffraction measurements by P.C. Gross and L.O. Brockway (14) suggest the existence of resonance structures  As there is only exchange of places by bonds, these resonating structures are possible by the parachor theory of resonance.

Sulphur trioxide can be represented by three equivalent structures, which have the same parachor. The resonance therefore seems to be possible. However, the observed value of parachor as given (30) by Sugden[30] 103.6 does not support these structures. The explanation forwarded by Sugden (29) that it is due to association does seem possible. It is suggested that in the case of sulphur trioxide a third structure is predominating and contributing towards resonance. The parachor value for this structure is 88.2 much lower than the observed value 101.4. It appears that there is 45% contribution by this structure towards resonance. In case of sulphur trioxide however there seems to be only one structure possible, consisting of single bonds.



The calculated value for this structure is 103.8 which is practically the same as the observed value 103.6.

To nitrogen dioxide we can assign the resonating structure



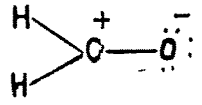
consisting of three electron bonds, since in these structures the bonds only exchange places and there is no change in parachor and hence resonance is possible on the basis of our parachor theory. It is interesting to note that the electron diffraction results of L. R. Maxwell, V. M. Mosley and L. S. Deming (31) have given no reliable information about the configuration of molecule. Parachor theory, however, lends support to the possibility of the resonance between the given structures.

The resonating structure of chlorine dioxide molecule can be explained on the same lines as nitrogen dioxide. They both contain a three electron bond. Again here, there is only change of place by the bonds and hence there will be no change in parachor. The resonating structures are confirmed by the work of P. Frisch and H. J. Schumachar (32) who observed that the Cl-0 distance in the chlorine dioxide molecule is 1.53 A° compatible with the above structures.

Ozone.—According to W. Shand and R. A. Spurr (24) the electron diffraction method indicates a symmetrical angular tructure for ozone with a bond distance 1.26 A°. However, according to parachor theory, two resonating structures are possible, since there is only an exchange of place by the bonds and hence there is no change in parachor. The spectroscopic work by Penny (22) and Sutherland supports these structures.

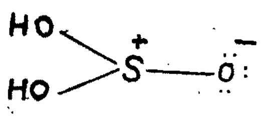
Hydrogen peroxide.—The observed parachor of hydrogen peroxide is 69.4. This is much lower than the calculated value 74.2 for the normal structure H-O-OH. It is therefore suggested that resonance occurs between structures. The two structures will have

$H—O—O—H$ and



the same parachor, but due to polar nature of the later structure, the parachor value will be lowered as is observed. The existence of hydrozen peroxide corresponding to the second structure had been confirmed by Gerb and Harteck. (11)

Sulphurous acid.—The sulphurous acid forms two ethyl sulphites and hence can have the resonating configurations:—



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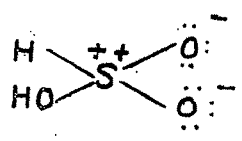
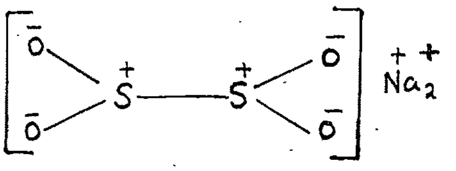
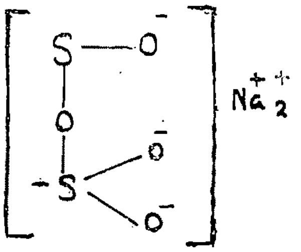


The resonance between these structures is possible on the basis of parachor theory, since there is no change in parachor.

The structure of thiosulphates has not been definitely established. Claims for the two structures have been forwarded (38). It is suggested that resonance between these structures occur as there is no change in parachor.

Various constitutional formulae have been suggested for hyposulphites. Thus sodium hyposulphite may be





The resonance between these configurations is possible according to our theory of resonance as there is only exchange of places by bonds.

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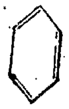
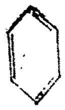
RESONANCE STRUCTURE AND PARACHOR

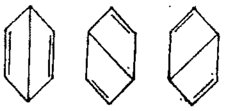
PART II.—RESONANCE STRUCTURES OF RING COMPOUNDS

By W. V. BHAGWAT AND R. P. SHUKLA, *Department of Chemistry, Holkar College, Indore.*

In this discussion of various examples of resonance of ring compounds, the structures in which a double bond changes into two rings of four have also been considered, along with those resonating structures in which there is only change of places by the bonds in the molecules.

Benzene : According to Kekule, the benzene has the structure  which is satisfactory for many purposes. However, there are two of these structures; the other being,  This requires the existence of two ortho-disubstituted derivatives. No instance is however known when two isomers have been isolated. Further, benzene is not so reactive, which is the characteristic of ethylene derivatives. It was suggested that there was a rapid oscillation between the two Kekule structures. We now explain it by saying that resonance occurs between these two structures. The molecule thus gains a considerable stability. On the basis of our theory, the two configurations will have identical parachors and resonance becomes possible. The observed value of parachor 206 is little smaller than the calculated value 207·1, the slight contraction being due to resonance.

The importance of our theory is however more realised when it is shown that it predicts the existence of Dewar's structures, in addition to Kekule's structures. The difference between these three structures and Kekule's is, that one double bond has disappeared and two rings of four are formed. This does

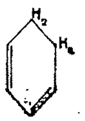


not alter the parachor and hence these structures should also contribute towards resonance.

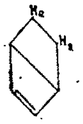
On quantum mechanical basis these structures are less stable and should therefore contribute less towards resonance. We arrive at a similar conclusion on parachor basis. There is a controversy whether such a structure should be considered to be made of two rings of four or a ring of six should also be included in it. Since the structure is coplaner, we cannot add a ring of six, as two rings of four include the whole structure. Thus in Dewar's structure there is a parachor decrease of 6·1 units, corresponding to the disappearance of a ring of six. Now, the Kekule and Dewar's structures have not the same parachor, although the variation is small and hence their contribution will be less. The observed lowering in the parachor of benzene may be due to the slight contribution by Dewar's structures. Benzene can have other configurations, but in these cases, one or two double bonds disappear, thus causing a very large parachor decrease; compared to Kekule's structure. Hence their contribution will be nil.

The above detailed consideration will explain the second significant observation why the parachor of double bond is twice that of a ring of four.

We may now turn to the case of dihydrobenzene or cyclohexadiene. This compound is shown by the structure



However, Dewar's structure is possible

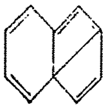


The difference of parachor between these two structures is of 6·1 units. The resonance contribution therefore will be less. This is supported by quantum mechanical considerations (3). It is observed that the energy level corresponding to former is 1·5 and 1·73 due to latter. We know that when only single low energy structure can be drawn, but there are contributions from one or more structures of appreciably high energy, the resonance stabilisation will be small and the properties of the substance will be to a large extent adequately represented by the proper structure of the lowest energy.

However, when benzene is further hydrogenated, only a single double bond is left and the case is similar to ethylene. There are no resonating structures, and tetrahydrobenzene is represented by the characteristic classical structure.

Naphthalene : For naphthalene the conventional valency bond structure is the Erlenmeyer's structure. There are two structures other than this which differ from it only in a distribution of the bonds. The parachor of these three structures will be the same, and hence resonance can occur between them, as they satisfy the parachor condition for resonance. The parachor theory therefore arrives at the same conclusion as by electron diffraction and other methods.(12)

Dewar's structures are also possible in case of naphalene. Some of these are shown below:—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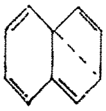
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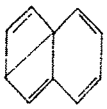
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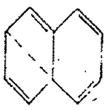
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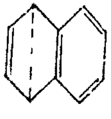
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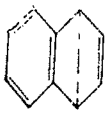
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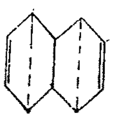
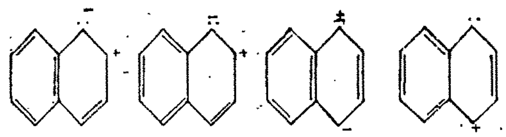

VII

In structure I, two double bonds disappear and four rings of four are formed. This does not bring about a change in parachor compared to the Erlenmeyer's structure. In structures II to VII one double bond disappears and two rings of four are formed. Again there is no change in parachor. However, as discussed in case of benzene, two rings of six apparently disappear from structure I, while one ring of six vanishes from the structures II to VII. Thus the parachor defect for the structure I is 12.2 and it is 6.1 for the structures II to VII. Since there are numbers of structures with the same parachor, resonance gives them some sort of stabilization, although its contribution to Erlenmeyer's structures should be small, since their parachors are not identical, a condition necessary for complete resonance. The observed parachor of naphthalene(1) is 312.5 while the calculated value for Kekule and Dewar's structures are 313.8 301.6 and 307.7 respectively. Our parachor theory of resonance therefore supports Kekule's structures with very slight contribution by other structures, since the observed value is somewhat smaller than what is required for Kekule's structures. The view is supported from the results obtained by other methods (1).

Polar resonating structures are also suggested to explain the choice of substitution. However, as yet no general qualitative rules have been formulated (1).

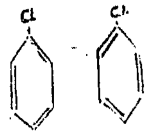


Some of these polar structures are shown above. These unstable structures can get stabilised due to resonance, since there are a number of them of this type. However, in all cases one double bond altogether disappears or there is a large parachor decrease of 23.3 units. Resonance between these and Kekule's structures is not supported by parachor theory of resonance. Further the parachor of naphthalene 312.5, as observed, supports our theory.

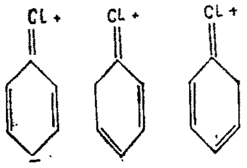
Anthracene and Phenathrene : It is possible to write four Kekule's structures, for anthracene and five for phenathrene. There will be no change in parachor, and hence resonance between these structures should be possible according to our theory. This is supported by electron diffraction and other methods. Several Dewar's structures will be possible, which will result in the disappearance of double bonds and consequent appearance of rings of four, double in number, to balance the parachor decrease. But a further decrease will be casued due to appearance of an equivalent number of rings of six. Parachor of these structures therefore will be smaller than that of Kekule's structures and hence resonance between Kekule and Dewar's structures on the basis of parachor theory should be negligible. The calculated value of parachor for the Kekule's structure is 418.9 for anthracene, while the experimental value as obtained by Bhatnagar and Singh (1) is 414.1, somewhat smaller. This may be due to contribution by Dewar's structures, whose parachor values are smaller by 6.1, 12.2 and 18.6 units, according as one, two or three double bonds changed into double the number of rings of four. The parachor theory of resonance therefore accounts very satisfactorily for observed results.

We have shown in the above discussion that whenever benezene type structure is involved, there is a possibility of representing its resonance with Dewar's structure. However, the contribution by such structure is negligible, since there is a parachor defect. Henceforth these structures therefore will not be discussed although they may be possible. Previous discussion is enough to show the application of the observation that the parachor of a double bond is twice the parachor of a ring of four. This observation is not accidental but can be used to explain the possibility of resonance with Dewar's structures wherever possible.

Chlorobenzene: The principal structures in chlorobenzene are:—

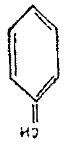


The resonance is possible, since there is no change in parachor. The observed parachor of chlorobenzene(17) is 243·9 which is very near the calculated value 244·3. It is suggested chlorobenzene may have the additional resonating structures of polar type.

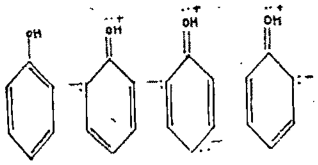


Again in these structures there is only a difference in the distribution of the bonds and hence there is no change in parachor. Resonance between these and the previous structures is therefore possible according to our theory. The polar nature is expected to cause a lowering in parachor. However, the observed lowering is very small.

Phenol : Phenol is represented by the configuration

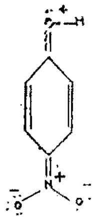


it can have the resonating structure



The observed parachor of (1) phenol varies from 220.2 to

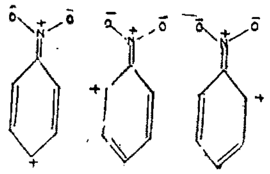
224.8. The calculated value 227.1 is much higher. The lowering therefore may be due to the contribution by the polar structures, which have apparently the same parachor, but a contraction is possible due to the internal attraction. The parachor theory therefore supports the resonance between all these structures. This view is confirmed from the observation that the acid constant of phenol is much larger than that of aliphatic alcohols(13). In case of nitrophenol an additional resonance structure is suggested by Pauling(13).



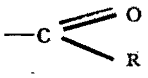
On the basis of our parachor theory it is possible, since there is only a difference in the distribution of bonds, which keeps the parachor constant. The observed value for the parachor(16) for both *m*-nitrophenol and *p*-nitrophenol is 283, while the calculated value is 286. The lowering in parachor therefore supports the resonance with polar structures. The case of *o*-nitrophenol is complicated due to the possibility of hydrogen bonding. The observed value 274.1 by the same authors is too low compared to the calculated value. 286

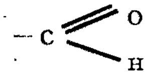
Nitrobenzene : All the normal resonating structures for nitrobenzene have the parachor value 265; and hence the resonance is possible according to our theory. The observed value 262.5 by Sugden(17) is in accordance with these structures, the lowering being due to the polar nature of these structures.

Other resonating structures have also been suggested.



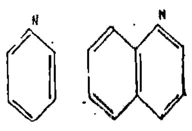
In these structures there is a disappearance of a double bond and hence the previous structure differs in parachor value by 23.2 units. On the basis of parachor theory, the resonance between these and previous structures is not possible.

In case of aromatic  $—C\genfrac{}{}{0pt}{}{\nearrow O}{\searrow R}$

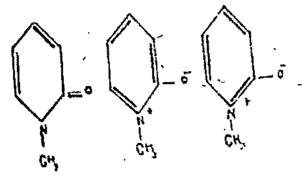
and  $—C\genfrac{}{}{0pt}{}{\nearrow O}{\searrow H}$ groups, similar polar structures are suggested in addition to normal structures. The parachor theory on the same grounds as in case of nitrophenol does not support their contribution to resonance.

Similar resonating structures for aniline become possible, as there is no change in parachor, because there is only an exchange in the position of bonds in these structures. The parachor of aniline calculated for these structures is 236.7. However, the observed (8) value 234.2, which is slightly lower, indicates the contribution by polar structures, since they tend to lower the parachor by internal attraction.

Heterocyclic molecules : The resonance of pyridine, pyrazine and related six-membered heterocyclic molecules is explained on the same line as benzene. The discussion of quinoline will be similar to naphthalene. The observed (17) parachor of pyridine is 199.8 and is 306 for quinoline (17). The calculated values are 197.7 and 304 respectively. These values indicate on the basis of parachor theory that Dewar's structures do not contribute towards resonance, the only important structures being those of Kekule.



To explain the nonreactivity of the carbonyl group in pyridones quinolones, the structures of the following type are suggested. Thus for N-methyl-2-pyridone we have



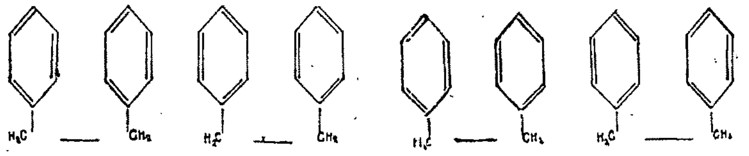
Since in all these cases parachor will be the same, as the only difference in them is the distribution of bonds. Our theory therefore supports the resonance between these structures.

The case of cyaneluric nucleus $C_6 H_7$ several (eighteen) resonating structures are suggested (14) in addition to the two valency bonds structures. It will be clear that all these structures have the same number of six-membered rings and the only difference is the distribution of bonds in them. This does not result in the change in parachor and hence the parachor theory of resonance supports the suggestion of L. Pauling and J. H. S. Sturdivant (14).

L. Pauling (11) suggests similar resonating structures of five-membered rings in furane, pyrrole and thiophene. These structures involve only the exchange of places by the bonds and hence are supported by our parachor theory. The parachor of thiophene (15) is 189.3 of pyrrol is 164.7. The calculated values are 190.7, 172.1 respectively. The lowering in parachor may be due to the contribution by the polar structures (II to IV).

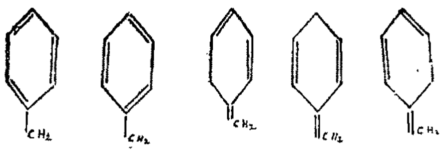
Free radicals: The explanation of the stability of free radicals was a problem when their existence was established by Gomburg in 1900. According to modern theory it is due to resonance of the free valency among many atoms (16).

1 ; 2 Diphenyl ethane has the resonating structures,



which are possible according to our theory as there is no change in parachor.

Each of the free radical of 1:2 diphenyl ethane can resonate amongst the five structures

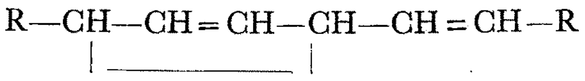


Parachor theory supports these resonating structures as there is only a change in the distribution of bonds, and thus confirms Pauling's (10) view.

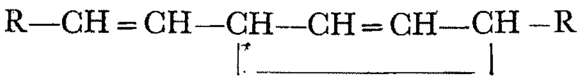
Conjugated systems: In case of linear conjugated system of type

$$\mathrm{R{-}CH{=}CH\quad CH{=}CH{-}CH{=}CH{-}R}\qquad (I)$$

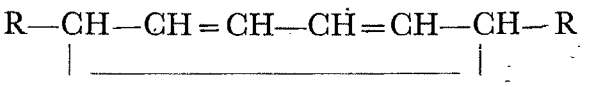
it is not possible to have another structure merely arranging the single and double bonds and without altering the charge on any of the atoms. However, structures of the type



$$\mathrm{R{-}\underbrace{CH{-}CH{=}CH{-}CH}{-}CH{=}CH{-}R}\qquad (II)$$



$$\mathrm{R{-}CH{=}CH{-}\underbrace{CH{-}CH{=}CH{-}CH}{-}R}\qquad (III)$$



$$\mathrm{R{-}\underbrace{CH{-}CH{=}CH{-}CH{=}CH{-}CH}{-}R}\qquad (IV)$$

can be written. But they have not the same parachor as (I). In II and III a ring of four is formed at the cost of a double bond. The parachor decreases therefore by 11.6, while this decrease is of 17.1 units in case of structure (IV). We can have polar structures also

$$\mathrm{R{-}\overset{+}{C}H{-}CH{=}CH{-}CH{=}CH{-}CH{-}R}\qquad (V)$$

$$\mathrm{\overset{-}{R}{-}CH{-}CH{=}CH{-}CH{=}\overset{+}{C}H{-}CH{-}R}\qquad (VI)$$

in which a double bond vanishes and thus causes a parachor defect of 23.2 units. The resonance structures II to IV are therefore not possible on the basis of parachor theory. According to L. G. S. Broker (5) from the consideration of the resonance energy only a single structure will dominate. The parachor theory supports this view.

According to Thiel's rule, butadiene should form the dibrome compound

$$CH_2Br{-}CH{=}CH{-}CH_2Br$$

The main product however is

$$CH_2Br{-}CHB,{-}CH{=}CH_2$$

The first product assumes the resonating structures

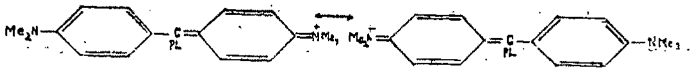
$$\overset{+}{C}H_2{-}CH{=}CH{-}\overset{-}{C}H_2$$

According to parachor theory this is not possible, since it contains one double bond less than the normal structure

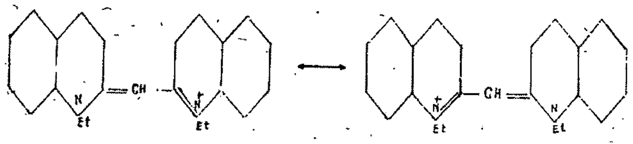
$$CH_2{=}CH{-}CH{=}CH_2$$

and hence has a parachor defect of 23.2 units. The parachor theory therefore explains why Thiel's rule fails.

Case of conjugated system of aromatic compounds is different. Here resonance structures can be formed by rearranging the bond and consequently without any change in parachor. The parachor theory therefore supports the resonance between such structures. In case of organic dyes the existence of colour is explained by Bury on the ground that they could be represented as resonance hybrids. His conclusion is therefore supported by the parachor theory. Following examples are given to illustrate it.



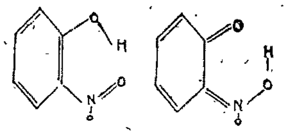
Malachite green ion



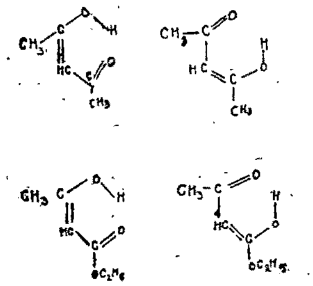
Cation of cyanine dye derived from quinoline.

Some complicated structures: The structures of *o*-nitro-phenol, aceto acetic-ester, diacetyl acetone and corboxylic acids are rather complicated due to the possibility of hydrogen bonding. We have however discussed their structures here only from the viewpoint of resonance.

o-nitro-phenol can have the structure



while acetoacetic ester and diacetyl acetone can be represented as



since in all these cases there is a difference in the distribution of bonds only, the parachor of resonating structures remain the same. The parachor theory therefore makes the resonance possible. Sidgwick (2) supports these structures. The observed parachor of acetylacetone (17) is 245.2, while the calculated value is 247. A slight decrease which has been observed may be due to resonance. The parachor theory therefore confirms the resonance between these structures. The value for *o*-nitro-phenol is 274 and is much lower than the calculated value 285.7. This may be due to hydrogen bonding. Although the possibility of resonance between the two structures of *o*-nitro-phenol is predicted by the parachor theory, the actual parachor results suggest a different type of configurations. This point will be discussed separately.

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PARACHOR AND RESONANCE

PART III.—RESONANCE STRUCTURES IN WHICH TWO DOUBLE BONDS ARE REPLACED BY A TRIPLE BOND AND A SINGLE BOND.

By W. V. BHAGWAT and R. P. SHUKLA, *Holkar College Indore.*

Carbon hioxide.—Let us take the case of carbon dioxide. According to classical theory it is represented as

$$O=C=O$$

However, according to the parachor theory of resonance, when there is no change in parachor in the alternative structures, resonance is possible. We know that if the two double bonds in carbon dioxide are replaced by a triple bond and a single bond, there will be no change in parachor. Further there will be a contraction due to the shortening of inter-atomic distances, when a double bond changes to a triple bond. Thus another parachor condition of resonance is satisfied. We can therefore write the alternative resonating structures for carbon dioxide as

$$\overset{+}{O}\equiv C-\overset{-}{O} \quad \text{and} \quad \overset{-}{O}-C\equiv \overset{+}{O}$$

Thus the carbon dioxide molecule is a mesomaride, between the double bond type and excited triple bond types.

The above view is supported from the crystal structure of carbon dioxide as determined by the X-ray method which shows that the molecule is linear. The bond distances in carbon dioxide were found by Wierl to be 1.13A, which is much lower than the expected value of 1.28 A for pure C-O double bond. This again supports the resonating view. The structure

$$O-C-O$$

is impossible on the basis of our theory, since it amounts to disappearance of two double bonds and hence a parachor variation of 46.4 units will occur. The electron diffraction and other methods do not support this structure.

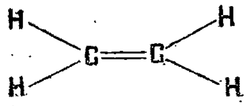
	$O=C=O$	$\overset{+}{O}\equiv C-\overset{-}{O}$	$\overset{-}{O}-C\equiv\overset{+}{O}$	$O-C-O$
C—O distances, A°	1.28 1.28;	1.28 1.43;	1.43 1.13;	
Total A°	2.56	2.56	2.56	2.30
Heat of formation	Cal.348	Cal.350	Cal.350	Cal.380.

The parachor of carbon dioxide calculated from the above structures is 90, while the value observed by Quinn (21) is very low 77.5. This lowering cannot be explained completely on the basis of the polar nature of the two resonating structures. An alternative structure for carbon dioxide is possible

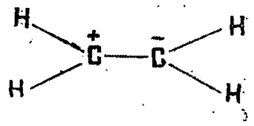
$$:\overset{-}{\ddot{O}}-\overset{+}{C}=O \qquad \text{and} \qquad O=\overset{+}{C}-\overset{-}{\ddot{O}}:$$

The parachor for this structure is 68. It appears therefore that the resonance occurs between these five structures.

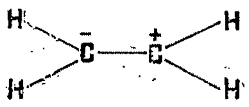
Ethylene.—Ethylene has the classical structure



Other possible structures can be polar

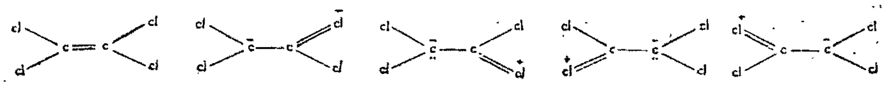


and



Both these polar structures are unstable and their parachors will be 23.2 units less than the classical structure, since a double bond has disappeared. The resonance between polar structures and classical one, is therefore not to be expected according to our theory, as there is an appreciable change in parachor. The observed parachor of ethylene 99.5 corresponds well with the calculated value 101 for the double bond structure of ethylene. Ethylene therefore can have only one structure. This is verified by electron diffraction and other methods. Obviously the two polar structures have the same parachor, but as they are not stable and are not stabilised by resonance, the structures of the type are too few, (two only) their contribution is nil.

Tetra-chloroethylene.—Tetra-chloroethylene can have four polar structures in addition to the classical structure.



The parachor of the polar structures is practically the same as that of the classical structure. Further, as there is a number of these structures, they become stabilised due to resonance. Thus resonance between all these five structures will be possible on the basis of parachor theory. It will be clear from above that due to polar structure C-C link should have a greater single bond character and therefore be larger than in ethylene. This is confirmed by the results of electron diffraction method. In case of tetra; chloroethylene (5) it is 1.38 A°, and it is 1.34 A° in ethylene. (24)

The above examples discussed in detail will clearly show the method of approach to resonance from parachor standpoint and it will be seen that its conclusions are identical with those drawn from the results of the other methods. Examples therefore can now be multiplied.

Carbondisulphide.—The structure of carbon disulphide can be written as

$$S=C=S,\quad \overset{-}{S}\equiv C\text{——}\overset{+}{S},\quad \overset{+}{S}\text{—}C\equiv \overset{-}{S}\qquad S=\overset{+}{C}\text{—}\overset{-}{\ddot{\underset{..}{S}}}:\qquad \overset{-}{\ddot{\underset{..}{S}}}:\text{—}\overset{+}{C}=S$$

The parachor of the first three structures will be the same, since there is only a difference in the distribution of bonds. But in the latter two structures there is a parachor decrease of 23.2 units due to the disappearance of a double bond. The observed parachor of carbon disulphide (26) is 144.7, while the calculated one for the first two structures is 147.6. It is clear therefore that unlike carbon dioxide there will be no contribution to resonance from the latter two structures. The slight decrease in parachor is due to the polar nature of the three resonating structures. They cause contraction in molar volume due to internal attraction. This is supported from the study of bond distance for C-S in carbon disulphide (7) which comes to be 1.54A°. Resonance energy of carbon disulphide also confirms the above conclusion.

Carbon oxysulphide. - Carbon oxysulphide can be written as

$$S{=}C{=}O,\quad \overset{+}{S}{\equiv}C{-}\overset{-}{O},\quad \overset{-}{S}{-}C{\equiv}\overset{+}{O},\quad \overset{-}{:\ddot{\underset{..}{S}}}{-}\overset{+}{C}{=}O \text{ and } S{=}\overset{+}{C}{-}\overset{-}{\ddot{\underset{..}{O}}}{:}$$

The observed inter-atomic distances (7) C—O = 1.16A° and C—S = 1.56A° agree well with the values C—O = 1.15° and C—S = 1.53A° calculated for equal resonance among the first three structures. On the parachor basis the first three structures can have resonance as they will have practically the same parachor. In last two cases there will be a parachor defect of 23.2 units and hence resonance between the first three and the last two is impossible. The parachor theory therefore explains the resonance between the first three structures.

Carbon suboxide.—The structure of carbon suboxide C_3O_2 can be represented as O=C=C=C=C=O. It will be observed that there are four double bonds. If they change to triple bonds and two single bonds, there will be no change in parachor. Further, a change of double bond to triple bond means contraction. Thus parachor conditions for resonance are satisfied. On the basis of our theory, carbon suboxide may have the resonating structures

$$\overset{+}{O}{\equiv}C{-}C{\equiv}C{-}\overset{-}{O} \quad\text{and}\quad \overset{-}{O}{-}C{\equiv}O{-}C{\equiv}\overset{+}{O}$$

in addition to the classical structure. This view is supported from the study of electron diffraction results, since observed C-C distance 1.30A° and C-O distance 1.20A° are shorter than the usual interatomic distances required for a double bond[3].

Nitrous oxide.—According to Baily and Casie (1) the structure of nitrous oxide is best represented as

$$\overset{-}{N}=\overset{+}{N}=O$$

According to our parachor theory the two double bonds, if changed into a single bond and a triple bond, there will be no change in parachor. Nitrous oxide therefore can have a resonating structure

$$N\equiv\overset{+}{N}-\overset{-}{O}$$

A third structure $\overset{=}{N}-\overset{+}{N}\equiv\overset{+}{O}$ is possible, but will be due to adjacent charge rule. (16) Parachor theory therefore supports the resonance between the first two structures of nitrous oxide.

The parachor of nitrous oxide (22) observed experimentally is 80, while the calculate d value is 91.4. The deviation seems to be very large. However, this is a typical case in which all structures are polar and hence the expected lowering in parachor is much larger. The part of excess of lowering observed may be attributed to inaccuracy of results.

The dipole moment should be large if only one structure is possible. The molecule should have very low dipole moment if both structures are resonating, since their moments are in opposite directions. The observed dipole moment of nitrous oxide is zero. Hence it confirms the resonating structures given above. The view is further supported by N-N bond (16) distance determined by electron diffraction method. This comes out to be 1.12A°. The observed bond distance is 1.19A° for N-O distance. These distances are smaller than what corresponds to double bond distances for N-O and N-N bonds.

Hydrazoic acid.—Hydrazoic acid may be represented structurally as

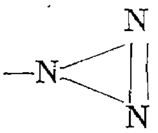
$$\mathrm{H{-}N{=}\overset{+}{N}{=}\overset{-}{N}}$$

and hence on similar grounds as nitrous oxide can have the resonating structure,

$$\mathrm{H{-}\overset{-}{N}{-}\overset{+}{N}{\equiv}N}$$

As two double bonds change into a triple bond and a single bond, there is no change in parachor and hence resonance becomes possible. Such resonating structures should give very small dipole moment to Hydrazoic acid. This is confirmed by the work of Shomaker and Spurrs. (25) Electron diffraction results [13] give the bond distance for N-N as 1.24A° and 1.13A° compatible with the above structures.

Azido grouping.—The parachor value for azido group is found to be 77.2 by Lindeman and Thiele. (12) This is smaller than the calculated value 82.3 for open chain structure. It was suggested therefore that the structure is a closed one.



The parachor value for this structure is 77.4. However, inter-atomic distances and heat of formation (23) do not support this structure. Further the dipole moment of Azides (16) is very small. This is in contradiction with triangular structure. Azido group can be represented as

$$\mathrm{{-}N{=}\overset{+}{N}{=}\overset{-}{N}}$$

and as such can have the resonating structure

$$\mathrm{{-}\overset{-}{N}{-}\overset{+}{N}{\equiv}N,}$$

in which two double bonds change into a triple bond and single bond resulting in no change in parachor. However, due to shortening of bond and the polar nature of structure there will be a contraction. Thus the observed parachor should be smaller than the calculated value. It is interesting to note that like hydrazoic acid, both the resonating structures are polar. Thus for all azides we have the structures,

$$R{-}N{=}\overset{+}{N}{=}\overset{-}{N} \quad \text{and} \quad R{-}\overset{-}{N}{-}\overset{+}{N}{\equiv}N$$

In all other cases considered, there was at least one normal structure. It is concluded therefore that the internal attraction will have greater contraction effect than the other cases. The fall in parachor value therefore should be greater due to resonance in this case. The parachor theory of resonance therefore very satisfactorily explains the low value of observed parachor. It is due to resonance and not due to triangular structure, which does not fit in with either dipole moment or heat of formation or inter-atomic distances.

Hunter and Samuel (11) have given the structure

$$-N{=}N{\equiv}N$$

and then tried to show that their structural values for atomic parachor reproduce experimental results. Unfortunately the assumed structure is incorrect and hence their claims are not supported even by their structural values.

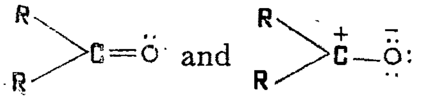
Diazo compounds.—Aliphatic diazo compounds such as diazomethane can be represented by the resonating structures.

$$\overset{+}{H_2C}{=}N{=}\overset{-}{N} \quad \text{and} \quad H_2\overset{-}{C}{-}\overset{+}{N}{\equiv}N$$

According to parachor theory, resonance is possible as there is no change in parachor. Electron diffraction (27) measurement supports this view. Lindeman and Thiele (12) however conclude that it should have cyclic structure on the basis of low parachor values. It will be clear from the discussion of hydrozoic acid and azides, that the lowering is due to resonance between the polar structures and not due to cyclic nature of azo compounds. The parachor theory therefore explains the parachor defect which otherwise leads to a structure not supported by other methods.

The parachor Theory of Resonance and Some Typical Structures.

Carbonyl group.—The determination of parachors of aldehydes and ketones indicate that the value 46 observed for CO group corresponds to the structure C=O (calculated value is 48). This value is only slightly low, but not so low as to indicate the ionic structure of carbonyl group as suggested by T. M. Lowry (13) and supported by L. Pauling (17)

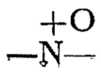


The observed dipole moment of acetaldehyde (18) acetone and methyl ethyl-ketone supports the resonating structure. However the two structures differ in parachor by 23.2 units as there is a difference of a double bond, between the two structures. If we assume with Pauling that both the structures contribute equally, a parachor defect of 11.6 should have been observed. This difference is quite large and can be detected experimentally. The failure to do so throws considerable doubt on the suggestion of T. M. Lowry (13) and L. Pauling (17) that carbonyl group has the resonating structures shown above.

Nitroso group.—According to L. Pauling, nitroso group should have the resonating structures

$$:\underset{\cdot\cdot}{\ddot{X}}-\ddot{\ }=\mathrm{O}: \quad \text{and} \quad :\overset{-}{\underset{\cdot\cdot}{\ddot{X}}}: \quad :\mathrm{N}\equiv\overset{+}{\mathrm{O}}: \quad \text{(ionic structure)}$$

He supports this from electron diffraction results. According to our parachor theory, the resonance does not seem to be possible, since it will result in a parachor increase of 23.2 units, as a double bond is replaced by a triple bond. The structure



$$\begin{array}{c} +\mathrm{O} \\ -\mathrm{N}- \end{array}$$

is equally improbable as it will cause a parachor decrease of 23.2 units. The observed value of parachor for nitroso group is 55 and corresponds to the double bond structure. Thus the nitroso group should have no resonance structure. The fact that nitroso compounds are dimagnetic (29) supports this view. This result supports our conclusion arrived at from the parachor theory. A two three bond structure is also suggested, but can be discarded on the same basis as above, as it will have different parachor.

Carbon monoxide.—On the basis of electronic theory of valency carbon monoxide has the structure

$$C{=}O.$$

This compound presents a difficult problem on account of the anomalous valency state of carbon. L. Pauling has put forward the evidence in favour of resonance between

$$:\overset{+}{C}::\overset{-}{\ddot{\mathrm{o}}}: \quad \text{and} \quad :\overset{-}{C}::\overset{+}{O}:$$

with preponderance towards the latter.

According to our theory, the resonance between these three structures is improbable, since this involves a change of a triple bond into a single double bond and not into two double bonds, resulting in the parachor decrease of 23.2 units. In other words the parachor condition of resonance is not satisfied. The parachor of carbon monoxide is 61.6. The calculated value for $\overset{-}{C}{\equiv}\overset{+}{O}$ is 69.6 and 48.0 for $\overset{-}{C}{=}\overset{+}{O}$. The parachor therefore supports the triple bond structure. The difference between the observed and calculated value is somewhat large but this lowering may be attributed to the polar nature of the molecule. It is made clear in the very beginning that there is no reason for assuming that this decrease is 1.6 in all cases, but should depend on the nature of the individual molecule. There may be a slight error also in the measurement as the value of parachor is for liquid carbon monoxide.

The work on heat of formation, dipole moment, the force constant and the spectrum observation of carbon monoxide supports our view (10). If carbon monoxide is represented by a double bond structure then a large dipole moment would be expected as in case of ketones and aldehydes. However, the actual value is very small, indicating that the main structure is

$$\overset{\leftarrow}{\mathrm{C=O}}$$

Pauling's work (*loc. cit*) on inter-atomic distances gives a bond length 1.13A° for C-O much shorter than required for a double bond and is still shorter than 1.24°, what is observed for carbonyl group.

The low value of parachor of CO does indicate some sort of resonance with the structures (If the measurements of

$$\overset{+}{:\mathrm{C}}=\overset{-}{\ddot{\mathrm{O}}}: \quad \text{and} \quad \overset{-}{:\underset{..}{\mathrm{C}}}=\overset{+}{\mathrm{O}}:$$

parachor of carbon monoxide are correct). These jointly will again have small dipole moments as the moments of the two structures are in opposite direction.

The parachor theory of resonance therefore successfully arrives at the same conclusion as by other methods. The formation of non-metallic carbonyl occurs through the sharing of the lone pair of the carbon electron with the metal.

$$\mathrm{M}\leftarrow\overset{\leftarrow}{\mathrm{C=O}}$$

This also supports that the main structure is $\overset{\leftarrow}{\mathrm{C=O}}$. It is interesting to note that according to L. Pauling the study of energy relations indicates that the structures are equally important. The

$$\overset{-}{:\mathrm{C}}\equiv\overset{+}{\mathrm{O}} \quad \text{and} \quad \overset{-}{:\mathrm{C}}=\overset{+}{\ddot{\mathrm{O}}}:$$

said conclusion is not supported by other methods, but parachor results indicate some evidence in its favour.

The methods other than parachor do not indicate the contributions of resonance structure $\overset{-}{\mathrm{C}}=\overset{+}{\mathrm{O}}$, while Pauling's work decides equally between the two resonating types. The parachor theory of resonance correctly explains the low value observed for parachor and gives due significance to both the structures, $:\overset{-}{C}\equiv\overset{+}{O}$ and $:\overset{-}{C}=\overset{+}{\ddot{O}}:$, the first predominating. Our theory therefore tells more accurately about the structure of carbon monoxide than the other methods.

The cynides and isocynides.—L. Pauling (20) suggests the following resonating structures for cyanides

$$R-C\equiv N \text{ and } R-\overset{+}{C}\equiv\overset{-}{N}.$$

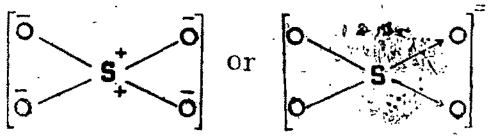
The large dipole moment shows that triple bond has a large amount of ionic character and the two structures apparently being of equal importance. Our theory of resonance suggests that the resonance is impossible, since such a change will involve a change of a triple bond into a single double bond and hence there will occur a large variation of 23.2 units in parachor. The value for parachor of $C\equiv N$ and $C=N$ group as calculated is 64 and 39 respectively, while the observed value from the study of nitriles is 64. It is clear therefore from parachor results, that the only structure that should predominate is $C\equiv N$. This is supported by the observed C-N distance 28 in methyle cyanide 1.16±0.02A°. The parachor theory of resonance therefore is more satisfactory in explaining the observed results.

In case of isocyanides, L. Pauling (19) again supports the resonating structures,

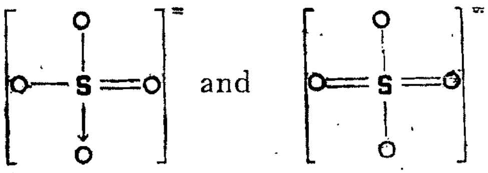
$$R-\ddot{N}::C: \text{ and } R-\overset{+}{N}:::\overset{-}{C},$$

The calculated values for parachor for—$\overset{+}{N}\equiv\overset{-}{C}$ and $N=C$ group are 64 and 40 respectively. The value observed in isocyanides is approximately 66. Thus the structure —$\overset{+}{N}\equiv\overset{-}{C}$ alone seems to be possible. The bond distance value 1.17±0.02A° (Brockway)4 observed cannot decide between the two possibilities since the calculated distances for the two structures are 1.19A° and 1.15A°, very near to 1.17A°. The fact that C—N—C atoms are observed to have a linear configuration, which is stable for $\overset{+}{N}\equiv\overset{-}{C}$ structure supports this structure alone. The dipole moment of isocyanides supports the triple bond structure. It will be clear therefore that our parachor theory of resonance successfully eliminates the double bond structure and explains the improbability of resonance between the two structures on the ground that they will have a large parachor deficit and thus confirms only the triple bond structure, which is also supported by dipole moment.

The structure of sulphate ion.—The electronic structure of sulphate ion can be represented as, but is unsatisfactory, since



Pauling[29] observed that the S—O distance in sulphate ion is 1.51A° and is smaller than single bond distance 1.70A°. He concludes therefore that some double bonds structure for S—O is present in the sulphate ion. Various structures are possible in addition to the one given above, but we shall consider only two as an example.



Since all oxygen atoms are equivalent, both these forms will have additional resonating structures, in which double bonds will exchange positions. The parachor theory of resonance, does not support the resonance between these structures, as one differs from another by 23.2 units successively.

It is interesting to compare the parachor result in case of sulphuric acid and sulphates they are compared with the calculated value for the structures I, II and III.

Compound	Pobs	Pcal.I	Pcal.II	Pcal.III
Sulphuric acid	144.8	159.2	180.8	202.4
Dimethyl sulphate	238.9	237.2	258.8	280.4
Diethyl sulphate	313.8	315.2	336.8	358.4
Dimethyl aniline bisulphate	469.9	474.0	495.0	517.2

It will be clear from the above results that the observed value agrees with the structure I and there is no indication of resonance with structure II and III. The parachor theory of resonance is therefore confirmed. Fajans suggested that bond distance may be due to ionic distortion consequent on polarisation and not due to resonance structures. Our parachor theory supports this view, which explains Pauling's observation that S-O distance in sulphate ion is shorter than what should be for a single covalent bond.

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MIXTURE LAW APPLIED TO PARACHORS OF ETHERS IN ALCOHOL AND HYDROGEN BONDING

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Hammick and Andrews,[1] were first to show that mixture law is applicable to parachors of liquid mixtures. Ray,[2] Kaveeshwar, Deshapande and Bhagwat[3] Lakhani and Daroga[4] have investigated this law using solids and inorganic salts.

The procedure adopted consists in finding out the parachors of ethers and alcohols separately and then of ethers in alcohols. The values obtained in solution are then compared with the observed values of pure liquids. The calculated values are not employed. This method balances any error due to slight impurity or any personal error. The method may involve a slight deviation from the absolute values, but the net conclusion remains unaffected. Surface Tension is determined by Jaeger's method.

Parachors of ethers and alcohols

Substance	Temp. C	Density	Surface tension	Parachor
Methyl alcohol	19	0·7995	22·48	87.24
Ethyl ,,	20	0·7980	22·62	125·9
iso-propyl ,,	21	0·7877	20·31	162·0
Amyl ,,	23	0·8119	21·85	234·7
Phenyl-methyl ether	18	0·9965	34·52	263·0
p-cresyl methyl ether	22	0·9681	31·54	299·0
di ethyl ether	20	0·7108	15·73	207·7

The samples were A. R. and were redistilled.

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Table II.

Parachor of phenyl methyl ether in different solvents. x, molar fraction of the ether; (1—x) molar fraction of the solvent; r, surface tension of the solution; d density of the solution. M*m* mean molar weight; P*m* observed parachor of the mixture; P*x* calculated parachor of the ether from solution.

Solvent	x	M_m	tC°	d	r	P_m	P_x
Methyl alcohol	0·1855	46·13	20	0·8766	25·87	118·7	257·1
	0·2580	51·66	19	0·8978	27·63	131·0	257·7
	0·4804	68·58	20	0·9393	28·80	168·0	255·4
	0·5471	73·78	20	0·9506	29·88	179·5	255·9
	0·5203	79·23	20	0·9832	29·35	191·8	254·6
	0·6806	83·81	21	0·9670	30·31	203·4	257·8
Ethyl alcohol	0·1622	56·14	20	0·8555	24·52	146·1	252·9
	0·2408	61·01	20	0·8748	25·32	156·4	253·5
	0·3468	67·59	20	0·8999	26·37	170·2	254·2
	0·4848	76·15	20	0·9245	28·97	191·1	258·8
	0·6378	85·66	20	0·9493	29·04	209·4	257·1
iso-propyl alcohol	0·2015	69·79	19	0·8439	22·76	180·5	253·6
	0·2911	74·07	20	0·8660	23·90	189·1	254·9
	0·5102	84·60	20	0·9109	25·30	208·3	252·9
	0·5657	87·26	21	0·9189	26·42	215·3	255·7
	0·6720	92·20	20	0·9430	27·31	223·9	253·9
Amyl alcohol	0·3233	94·61	20	0·8732	25·22	242·9	256·6
	0·4158	96·42	21	0·8863	25·77	245·1	257·6
	0·5512	99·17	22	0·9111	26·17	246·4	254·7
	0·6526	101·19	20	0·9285	26·83	248·0	254·2

Table III

Parachor of p-cresyl methyl ether

Methyl alcohol	0·1649	46·90	22	0·8654	23·89	119·8	281·3
	0·1778	48·06	21	0·8818	25·32	122·3	281·4
	0·3334	62·07	22	0·9059	25·67	155·3	286·4
	0·4079	68·79	21	0·9160	26·40	170·2	289·7
	0·6966	94·81	20	0·9350	27·43	232·0	294·7
Ethyl alcohol	0·1900	60·54	21	0·8565	24·02	156·5	288·4
	0·2138	62·33	20	0·8620	23·69	159·5	284·2
	0·2671	66·39	20	0·8788	24·56	168·2	285·1
	0·3755	74·63	19	0·8997	25·77	186·9	288·8
	0·4294	78·73	22	0·9252	25·69	196·0	288·9

TABLE IV

Parachor of di-ethyl ether

Methyl alcohol	0·2989	45·13	21	0·7638	18·75	122·9	204·9
	0·3927	48·56	21	0·7548	18·06	132·9	202·5
Ethyl alcohol	0·3175	54·97	22	0·7661	18·82	149·4	200·5
	0·3543	56·01	22	0·7625	18·56	152·5	201·3
iso-propyl alcohol	0·5732	68·13	23	0·7406	17·24	187·5	205·7
	0·6298	68·92	23	0·7362	17·19	187·8	202·5

DISCUSSION

It is well known that hydrogen atom under suitable condition can increase its co-valency by one[5]. The association of water molecules and of alcohol molecules is explained on this basis. According to Glasstone[6] there is reason to believe that an oxygen atom in an ether can combine with hydroxylic derivatives to form compounds, of the type R_2—H.O.R. Such compounds probably account for the solubility of ethers in water and provided other conditions are equal the solubility will increase the more the tendency of the R-groups in the ether to repel electrons. This repulsion will enhance the donation of the oxygen atom. Bennet and Phillip[7] have studied the solubility of ethers in water and have confirmed the view that the presence of an electron repelling group tends to increase the solubility. The evidence is thus in favour of existence of co-ordinated hydrogen. Sidgwick[5] has suggested that an increase in the effective covalency of hydrogen from one to two should cause a parachor decrease of approximately 12.8 units. Thus it is now known that actually the hydrogen bond is electrostatic[8] in nature and occurs between two negative groups. The strength of the bond is not constant. This decrease is not constant but varies according to the strength of hydrogen bond. Our parachor results indicate that when phenyl-methyl ether is dissolved in alcohols its parachor is about 255, while the observed for the pure liquid is 263. Similarly the values for p-cresyl methyl ether and diethyl ether in alcohols are approximately 288 and 202 respectively; while the values for these pure liquids are 299 and 208. It is clear, therefore, that there is a fall of about eight units for phenyl methyl ether and di ethyl ether while the decrease is of eleven units for p-cresyl methyl ether. The results, therefore, confirm the view that ethers when dissolved in alcohols form the compounds of the type R_2—H. O. R.

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LAMINAR FLOW IN A PLANE WAKE OF A COMPRESSIBLE FLUID

By M. RAY, *Professor of Mathematics, Agra College, Agra.*

1. *Introduction.*—The boundary-layer equations for a compressible fluid have often been used by many authors for studying steady laminar flow along a flat plate as well as in plane jets. Illingworth (1) and Toose (2) have recently studied the problem of plane jet when the Prandtl number is unity. Their method was to transform the boundary-layer equations by means of Mises transformation but they adopted different forms of Crocco's relation for the temperature distribution and so, though their methods were analytically similar, they arrived at transformation formulae which were functionally different. Illingworth also took up the problem of wake behind cylindrical obstacles and found a simple solution for any value of the Prandtl number.

In this paper the problem of plane wake in a compressible fluid has been studied following the method adopted by Toose. The problem has been simplified on the assumption that the variations of velocity and temperature at a large distance downstream are small and there the heat generated by dissipation can be neglected. In this case the restriction that the Prandtl number should be unity is not necessary and the results obtained are similar to those found by Illingworth. It is also found that when the velocity and temperature distributions are identical, the case degenerates to the corresponding problem for the incompressible wake. In this case the restriction that the Prandtl number is unity is reimposed.

2. *Basic equations.*—Very far downstream in the wake, if the motion is steady, the boundary-layer approximations hold good. The pressure would be nearly constant across a section of the wake, the transverse velocity small compared with the longitudinal velocity. Let u_0 be the undisturbed stream velocity and x be measured downstream from an unspecified origin in the neighbourhood of the obstacle.

The equation of motion in the x—direction is

$$\rho u \frac{\partial u}{\partial x} + \rho v \frac{\partial u}{\partial y} = \frac{\partial}{\partial y}\left(\mu \frac{\partial u}{\partial y}\right), \qquad \ldots\ldots(1)$$

and the equation of energy is

$$\rho u \frac{\partial i}{\partial x} + \rho v \frac{\partial i}{\partial y} = \frac{\partial}{\partial y}\left(\frac{\mu}{\sigma} \frac{\partial i}{\partial y}\right) + \mu\left(\frac{\partial u}{\partial y}\right)^2, \qquad \ldots\ldots(2)$$

where i is the heat-content and σ the Prandtl number

The equation of continuity is

$$\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) = 0; \qquad \ldots\ldots(3)$$

and the equation of state for a perfect gas is

$$\rho i = \text{const.} = \rho_0 i_0, \qquad \ldots\ldots(4)$$

suffix 0 denoting the value in the undisturbed stream.

We further assume that

$$\frac{\mu}{\mu_0} = \frac{i}{i_0} \qquad \ldots\ldots(5)$$

The boundary conditions are

on the axis of the wake $(y=0)$, $v=0$, ……(6)

and $\frac{\partial u}{\partial y}=0$, ……(7)

Outside the wake$(y \longrightarrow \infty)$, $u=u_0$ ……(8)

3. *Simplifications of the equations.*

When $\sigma = 1$, the equations (1) and (2) are satisfied by the Crocco's relation

$$i = A_1 + A_2 u - \frac{u^2}{2}$$

$$\text{or } i_0 - i = A_2(u_0 - u) - \tfrac{1}{2}(u_0^2 - u^2) \qquad \ldots\ldots(9)$$

Let us now put

$$u = u_0(1-\omega), \qquad \ldots\ldots(10)$$

$$\text{and } i = i_0(1-\omega_1), \qquad \ldots\ldots(11)$$

where ω and ω_1 are small quantities.

Neglecting squares and products of small quantities the equation (1) reduces to

$$\rho u_0 \frac{\partial \omega}{\partial x} = \frac{\partial}{\partial y}\left(\mu \frac{\partial \omega}{\partial y}\right), \qquad \ldots\ldots(12)$$

and neglecting the dissipation term, the equation (2) reduces to

$$\rho u_0 \frac{\partial \omega_1}{\partial x} = \frac{1}{\sigma} \frac{\partial}{\partial y}\left(\mu \frac{\partial \omega_1}{\partial y}\right), \dots\dots\dots\dots (13)$$

taking σ to be constant, not necessarily unity.

The equation (3) is satisfied by

$$\rho u = \frac{\partial \psi}{\partial y}, \quad \rho v = -\frac{\partial \psi}{\partial x} \dots\dots\dots\dots (14)$$

We now change the independent variables (x, y) to (x, ψ) by means of the transformation formulae

$$\left.\begin{aligned} \left(\frac{\partial}{\partial y}\right)_x &= \rho u \left(\frac{\partial}{\partial \psi}\right)_x = \rho u_0 (1-\omega) \left(\frac{\partial}{\partial \psi}\right)_x \\ \left(\frac{\partial}{\partial x}\right)_y &= -\rho v \left(\frac{\partial}{\partial \psi}\right)_x + \left(\frac{\partial}{\partial x}\right)_\psi \end{aligned}\right\} \dots\dots\dots\dots (15)$$

The equation (12) then becomes to our approximation,

$$\frac{\partial \omega}{\partial x} = u_0 \frac{\partial}{\partial \psi}\left(\mu \rho \frac{\partial \omega}{\partial \psi}\right).$$

Using (5) and then (4), the above equation gives

$$\frac{\partial \omega}{\partial x} = u_0 \rho_0 \mu_0 \frac{\partial^2 \omega}{\partial \psi^2} \dots\dots\dots\dots (16)$$

When the equation (13) is similarly treated, we get

$$\frac{\partial \omega_1}{\partial x} = \frac{u_0 \rho_0 \mu_0}{\sigma} \frac{\partial^2 \omega_1}{\partial \psi^2} \dots\dots\dots\dots (17)$$

To solve equations (16) and (17), let us put

$$\omega = A x^{-\frac{1}{2}} f(\eta), \quad \omega_1 = B x^{-\frac{1}{2}} f_1(\eta), \dots\dots\dots\dots (18)$$

where $\eta = \dfrac{1}{2\sqrt{u_0 \rho_0 \mu_0}} x^{-\frac{1}{2}} \psi \dots\dots\dots (19)$

We then get

$$f^{11}(\eta) + 2\eta f^{1}(\eta) + 2f(\eta) = 0$$

and

$$\left.\begin{aligned} & \\ & f_1^{11}(\eta) + 2\sigma \eta f_1^{1}(\eta) + 2\sigma f_1(\eta) = 0, \end{aligned}\right\} \dots\dots\dots\dots (20)$$

where dashes mean differentiations with respect to η.

Before we go to solve the above equations, we must see what conditions these functions $f(\eta)$ and $f_1(\eta)$ satisfy.

4. *Solutions of the equations.* From definition, we have

$$d\psi=\left(\frac{\partial\psi}{\partial x}\right)_\eta dx+\left(\frac{\partial\psi}{\partial\eta}\right)_x d\eta=\left(\frac{\partial\psi}{\partial y}\right)_x dy+\left(\frac{\partial\psi}{\partial x}\right)_y dx$$

where

$$\psi=2\sqrt{v_0\rho_0\mu_0}\,x^{\frac{1}{2}}\eta.$$

$$\therefore \sqrt{u_0\rho_0\mu_0}\,x^{\frac{1}{2}}\eta\;\;dx+2\sqrt{u_0\rho_0\mu_0}\,x^{-\frac{1}{2}}d\eta=\rho u\;\;dy-\rho v dx.$$

giving

$$\rho v=-\sqrt{u_0\rho_0\mu_0}\,x^{\frac{1}{2}}\eta, \quad\ldots\ldots\ldots\ldots(21)$$

and

$$\rho u dy=2\sqrt{u_0\rho_0\mu_0}\,x\tfrac{1}{2}d\eta, \quad\ldots\ldots\ldots\ldots(22)$$

From (21) we see that $v=0$ when $\eta=0$, thus $\eta=0$ corresponds to $y=0$.

From (22), we get

$$dy=2\sqrt{u_o\rho_0\mu_0}\;\;\frac{x^{-\frac{1}{2}}}{\rho u}d\eta$$

$$=2\sqrt{u_0\rho_0\mu_0}\;\;\frac{x^{\frac{1}{2}i}}{i_0\rho_0u_0(1-\omega)}d\eta, \text{ from (4) and (10)}$$

$$=2\sqrt{\frac{v_0}{u_0}}\;x^{\frac{1}{2}}\frac{1-\omega_1}{1-\omega}d\eta, \text{ from (11)},$$

$$=2\sqrt{\frac{v_0}{u_0}}\;x^{\frac{1}{2}}(1+\omega-\omega_1)d\eta,$$

approximately.

$$\therefore\; y=2\sqrt{\frac{v_0}{u_0}}\;\left[x^{\frac{1}{2}}\eta+A\int_0^\eta f(\eta)d\eta-B\int_0^\eta f_1(\eta)d\eta\right], \quad\ldots\ldots\ldots(23)$$

as $y=0$ when $\eta=0$.

This shows that $y\longrightarrow\infty$ corresponds to $\eta\longrightarrow\infty$.

Further

$$\frac{\partial\omega}{\partial y}=\rho u\;\frac{\partial\omega}{\partial\psi}=\rho u.\;Ax^{-\frac{1}{2}}f^1(\eta)\;\frac{1}{2\sqrt{u_0\rho_0\mu_0}}\;x^{-\frac{1}{2}},$$

so that the condition $\dfrac{\partial u}{\partial y}=0$ when $y=0$ or $\dfrac{\partial \omega}{\partial y}=0$ when $y=0$ reduces to the condition $f^1(\eta)=0$ when $\eta=0$.

Thus the boundary conditions are

$$\left.\begin{aligned} f(\eta)&=0 \text{ when } \eta=\infty \\ \text{and } f^1(\eta)&=0 \text{ when } \eta=0. \end{aligned}\right\} \quad (24)$$

Similar conditions hold also for $f_1(\eta)$.

We are now in a position to solve the equations (20).

The solutions corresponding to the conditions (24) are

$$\left.\begin{aligned} f(\eta)&=e^{-\eta^2} \\ \text{and } f_1(\eta)&=e^{-\sigma\eta^2}. \end{aligned}\right\} (25)$$

$$\left.\begin{aligned} \text{Thus } \omega&=Ax^{-\frac{1}{2}}\,e^{-\eta^2} \\ \omega_1&=Bx^{-\frac{1}{2}}\,e^{-\sigma\eta^2} \end{aligned}\right\} (26)$$

If D be the drag per unit breadth of the cylindrical obstacle. we have

$$\begin{aligned} D&=2\int_0^\infty \rho u(u_0-u)\,dy \\ &=4\sqrt{u_0\rho_0\mu_0}\int_0^\infty x^{\frac{1}{2}}\,u_0\omega\,d\eta \quad \text{from (22)} \\ &=4Au_0\sqrt{u_0\rho_0\mu_0}\int_0^\infty e^{-\eta^2}\,d\eta \\ &=2Au_0^2\rho_0\sqrt{\frac{\pi\nu_0}{u_0}} \end{aligned}$$

$$\therefore\ A=\frac{D}{2\rho_0u_0^2}\sqrt{\frac{u_0}{\pi\nu_0}} \qquad (27)$$

If $-2Q$ be the rate of transfer of heat from the fluid to the cylinder, we have

$$-2Q=2\int_0^\infty \rho u\,(i_0-i)\,dy=2\rho_0 i_0u_0B\sqrt{\frac{\pi\nu_0}{\sigma u_0}}$$

$$\therefore\ B=-\frac{Q}{\rho_0 i_0u_0}\sqrt{\frac{\sigma u_0}{\pi\nu_0}} \qquad (28)$$

We now complete the transformation
formula (23) between y and η.
From (23) we have, using (25), (27) and (28).

$$y=2\sqrt{\frac{\nu_0}{u_0}}\left[x^{\frac{1}{2}}\eta+\frac{D}{2\rho_0 u_0^2}\sqrt{\frac{u_0}{\pi\nu_0}}\int_0^\eta e^{-\eta^2}d\eta+\frac{Q}{i_0\rho_0 u_0}\sqrt{\frac{\sigma u_0}{\pi\nu_0}}\int_0^\eta e^{-\sigma\eta^2}d\eta\right]$$

$$=2\sqrt{\frac{\nu_0 x}{u_0}}\,\eta+\frac{D}{2\rho_0 u_0^2}\,\mathrm{erf}\,(\eta)+\frac{Q}{i_0\rho_0 u_0}\,\mathrm{erf}\,(\sqrt{\sigma}.\,\eta) \qquad (29)$$

5. *Incompressible liquid*—If the velocity distribution be similar to the temperature distribution

$$i.\,e.\ \frac{i}{i_0}=\frac{u}{u_0}$$

then $\omega=\omega_1$.

This is possible only when $\sigma=1$.

In that case, we get $y=2\sqrt{\frac{\nu_0 x}{u_0}}.\eta$ and

the case degenerates to that of a wake in an incompressible liquid.

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SLOW AND SMOOTH PERIODIC (MAGNETO-IONIC) FADING OF RECEIVED RADIO-SIGNALS IN RELATION TO IONOSPHERIC CONDITIONS.

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I. INTRODUCTION.

In earlier communications (1, 2, 3), the fading patterns of received radio-signals on various wave bands for different distances of transmission and different hours of observations, have been classified in seven groups (3), namely peaky random, non-peaky or slow random, quasi-periodic, slow and smooth periodic (magneto-ionic), peaky periodic, slow periodic superimposed with ripples and complex periodic fading, according to their theory and mode of formations (1 3). The object of the present communication is to analyse the fourth classification, i.e. slow and smooth periodic (magneto-ionic) fading in relation to various ionospheric conditions.

II. MAGNETO-IONIC FADING AND ELECTRONIC DENSITY IN THE IONOSPHERE

It may be recalled that the slow and smooth periodic fading is brought about by the interference between the ordinary and extraordinary ray reflections of the split-wave from the ionosphere due to magneto-ionic effect when the electronic density in the ionosphere is considerably low so as to be just enough for single reflection of the wave between the transmitting and receiving stations. These patterns of fading are usually slow and smooth. They are, therefore, called slow and smooth or magneto-ionic periodic fading. Table 1 contains the instances for the occurrence of such fading patterns.

TABLE I.

Slow and smooth periodic (Magneto-ionic)

Fig. Nos.	Date & time in I. S. T.	Wave band	Existing electronic densities in F2-region in Elec./c.c.	Elec./c.c. required for single reflection F2—layer
1.	12. 5. 47: 1852 Hrs.	19m Delhi	...	$1{\cdot}42\times10^6$—$1{\cdot}57\times10^6$ thin layer
2.	do 1848 Hrs.	do	...	do
3.	do 1859 Hrs.	do	1.04×10^6	do
4.	28.12.46: 0742 Hrs.	do	Starting with $1{\cdot}2\times10^6$ —$1{\cdot}6\times10^6$	For thick layers 1.93×10^6. Thermal expansion.
5.	11. 4. 47: 0750 Hrs.	19m. Delhi	$1{\cdot}3\times10^6$—1.6×10^6	For thick layer $1{\cdot}76\mathrm{X}10^6$ Thermal expansion

Columns 1, 2, 3 and 4 of the table contain fig. Nos., date and time in I.S.T., wave band, and the electronic concentrations existing in the F2-region at the hours of observations, respectively. The last vertical column No. 5, provides the electronic density required for single reflection for the thick and thin layers for the frequency used for transmission from Delhi. A comparison of the electronic densities given in column 4 and 5 of the table shows that the existing electronic densities in the F2-layer of the ionosphere during the hours of observations of slow and smooth periodic (magneto-ionic) fading as depicted in figs. 1-5, are just sufficient for single reflections. That is, the existing electronic concentrations in the F2-layer of the ionosphere are such that the wavelengths used on those occasions correspond to the maximum usable frequencies for transmission between Delhi and Banaras. Evidently then, the occurrence of such patterns of periodic fading on a particular frequency indicates the inadequacy of electrons in the ionosphere. Consequently it has often been found that after the occurrence of such periodic

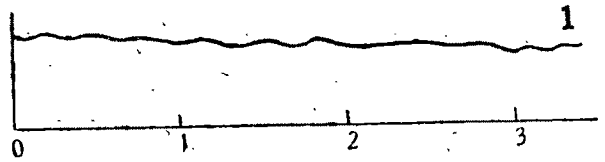

FIG. 1. Showing slow-smooth periodic (megneto-ionic) 12-5-47 at 1842 hrs. IST, 19 m Delhi. Intensity on vertical axis, time in minutes on horizontal axis.

fading, the signals have disappeared due to scarcity of electrons in the ionosphere.

III. MAGNETO-IONIC PERIODIC FADING AND DISAPPEARANCE OF RADIO-SIGNALS

(a) DISAPPEARANCE OF SIGNALS IN THE EVENING HOURS

As the fading patterns obtained, prior to the disappearance of the radio-signal on a particular frequency, belong to the category of slow and smooth periodic or magneto-ionic fading, it is desirable to draw the (P′,X) curve for explaining the sequence of events prior to the cessation of signals. It may be pointed out that P′ is the total path travelled by the wave between the transmitter and the receiver via the ionosphere and $X = \frac{fo}{fc}$ or $\frac{fe}{fc}$ where fo and fe denote the ordinary and extra-ordinary ray frequencies of the split wave due to magneto-ionic effect and fc is the critical frequency. Such curves have been shown in fig. 6-12 for the distance between Delhi and Banaras (678.4 km.). The continuous line in the figures represents the ordinary ray (P′,X) curve while the dotted ones show the extra-ordinary ray (P′,X) curves.

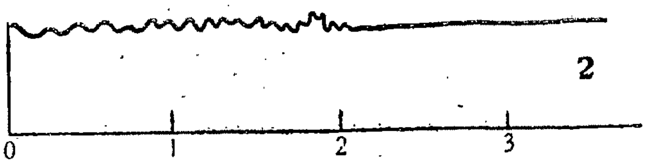

FIG. 2. Curve for 12-5-47 at 1845 hrs IST, 19 m Delhi.

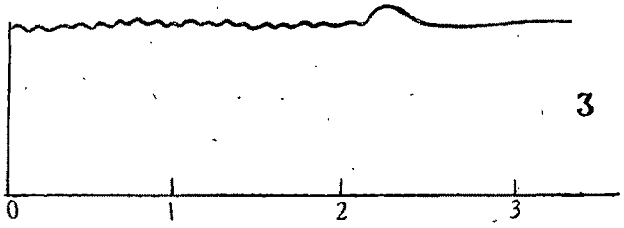

FIG. 3. Curve for 12-5-47 at 1859 hrs. IST, 19 m Delhi.

It may be noted that the (p′,x) curves shown in figs. have been drawn following the expressions (4) given by

$$D = Ym \; X \; Sin \; I_o \log \frac{1+x \; Cos \; I_o}{1-x \; Cos \; I_o} + 2 \; ho \; tan \; I_o \ldots\ldots\ldots(1)$$

$$\text{and} \quad p' = \frac{D}{Sin \; I_o} \ldots\ldots\ldots (2)$$

where D = the distance between the transmitter and receiver,

Ym = Semi-thickness of the ionospheric layer

$x = \frac{f_o}{f_c}$,

I_o = Angle of incidence at the Ionosphere

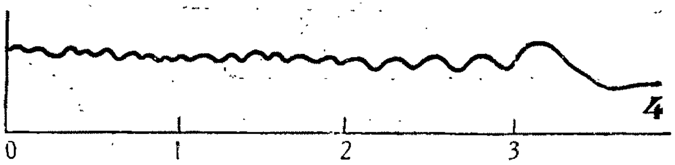

FIG. 4. Curve for 28-12-46 at 0845 hrs. IST. 19 m Delhi.

ho = The height of the lower boundary of the ionosphere and p′ = total path travelled by the wave between the transmitter and receiver via the ionosphere.

These curves have been drawn for three values of the ionosphere semi-thickness namely 10, 30 and 60 km, assuming the value of ho = 330 km. in each case.

For drawing the extra-ordinary ray component, the following formulae (5) were used:—

$$f_e = f_H \pm \sqrt{f_H{}^2 - 4f_o{}^2} \ldots\ldots\ldots (3)$$

$$\text{and} \quad f_H = \frac{He}{2\pi mc} \; (4)$$

where, fe = the extra-ordinary ray frequency

fo = ordinary ray frequency

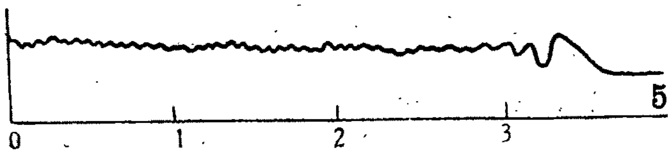

FIG. 5. Curve for 11-4-47 at 0750 hrs. IST. 19 m Delhi

f_H = Gyro-frequency
H = Magnetic field at the ionosphere
e = electronic charge
and c = velocity of light

It will be seen in the figs. 6—8 that the separation between the ordinary and extra-ordinary rays, is due to H = 0.2 Gauss and in figs. 9—11 due to H = 0.4 Gauss. In fig. 12, the extra-ordinary rays have been shown due to H = 0.2 and 0.4 gauss side by side on an extended scale for the sake of comparison.

The sequence of events before the disappearance of radio-signal (1) on 19 metre band from Delhi on 12-5-47 in the evening is shown in fig. 1-3. It will be seen that the daigram 1 represents the interference fringes produced by ordinary and extra-ordinary rays due to magneto-ionic splitting. As the density further diminishes, with the advance of time, the Pedersen ray begins to appear and thereby, the fading pattern changes to a more complicated wave shape as shown in the first portion of fig 2. After this, as the electronic density further decreases, the Pedersen ray disappears along with the lower ray and the signal is received only due to extra-ordinary ray. During this period, the intensity of the signal remains nearly constant as shown by the latter portion of fig. 2. This is followed by the appearance of the upper extra-ordinary ray which interferes with the existing lower extra-ordinary ray and consequently again gives rise to a simple periodic fading pattern as shown in fig. 3. As the lowering of electronic density continues, the intensity of the received signal is found to increase, and at the end, the signal disappears due to want of adequate amount of electrons

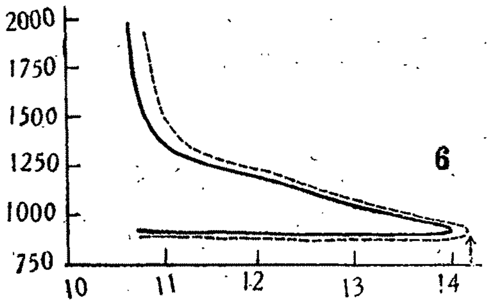

FIG. 6. Curve for ym=10 Km. H=·2 Gauss. P-Km on vertical xm on horizontal.

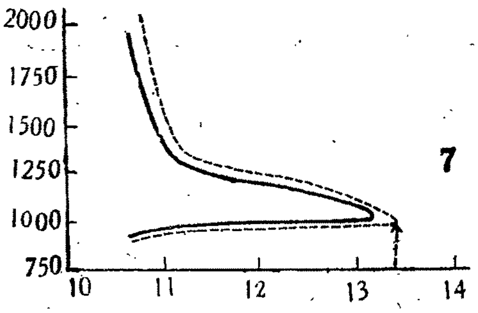

FIG. 7. Curve for Ym=30 Km. H=2 Gauss. P-Km on vertical. xm on horizontal.

in the layer. The cause of this enhancement of intensity, however, is explained later.

It may be noted that in the beginning of formation of the magneto-ionic fading discussed above, the electronic density in F2-layer was nearly 1.3 × 10^6 electrons/cc, which is the value nearing just enough for single reflection from F2-layer for the 19 metre band for transmission from Delhi. Towards the end when the signal disappeared, the electronic density in the F2-layer was found to have decreased to 1.04 × 10^6 electrons/cc. It is evident that the signal in the evening disappeared due to inadequacy of electrons in the inosphere for reflection of 19 metre band for transmission from Delhi.

(b) DISAPPEARANCE OF THE SIGNAL IN THE MORNING HOURS (6).

It has often been observed during our observations on fading of short wave radio-signals in the morning, sufficiently after ground sun-rise, that the received signal disappears suddenly, but it appears again after some time. It is generally assumed, however, that the signal which once appears in the morning, should continue as the electronic density in the ionosphere increases with the advance of the day. This conclusively goes to show that the morning disappearance of the radio signals mentioned above, and shown in figs. 4 & 5 on 19 metre band for transmission from Delhi, cannot be attri-

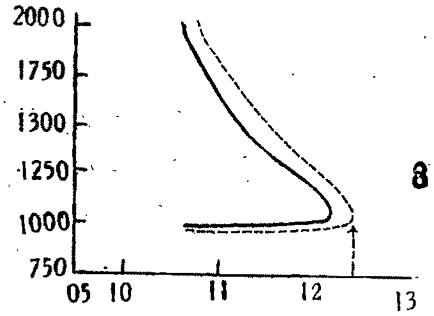

FIG. 8. Curve for Ym=60 Km H=.2 gauss

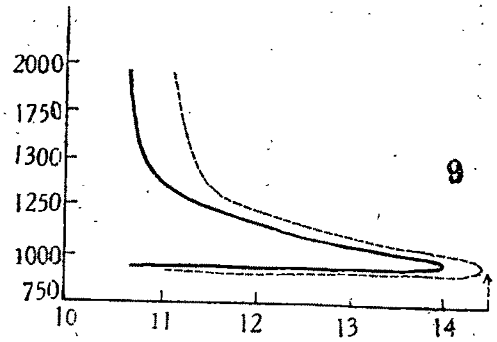

FIG. 9. Curve for Ym=10 Km, ho=300 Km=H=·4 Gauss. P—Km on vertical. xm on horizontal.

buted to the reduction of the electronic concentrations in the ionosphere, as has been considered for the evening disappearance of the signal mentioned before. Thus this morning temporary disappearance of the signal is evidently due to the cause different from that for evening disappearance of signal, which is discussed below :

On the occasions of morning disappearance of radio signals mentioned above (6), the fading pattern prior to cessation of signals was of slow and smooth periodic type. This suggests that the electronic density in the ionosphere had increased to the value to be sufficient for single reflection of the wave. The observed electronic densities in the F2- layer at the hours of observation agree with this conclusion as shown in column 4 of the table. The electronic density at the time of observation of

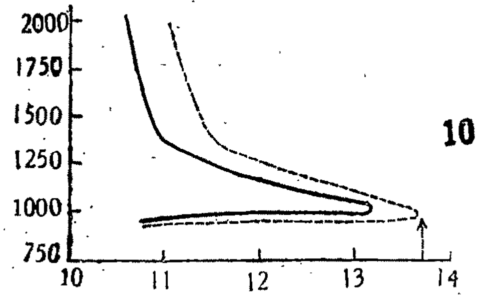

FIG. 10. Curve for Ym=30, ho=300 Km, H=·4 Gauss, P—Km, on vertical, xmon horizontal.

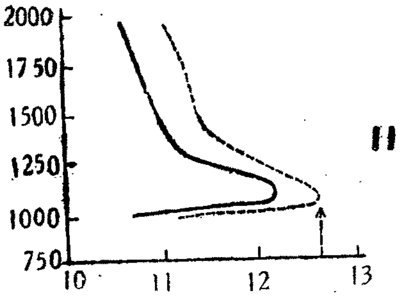

FIG. 11. Curve for Ym=60 Km, ho=300 Km, H=·4 Gauss. P—Km on vertical, xm on horizontal.

fading pattern (fig. 1) was nearly 1.21×10^6, later 1.6×10^6 electrons per c. c. and at the time of observation of fading shown in fig. 2, was 1.6×1.6^6 electrons/c. c. That is, in each case, it is nearly sufficient for single reflection with thin layer. Now with the advance of the day, the thickness of the ionospheric layer increases, the ratio $\frac{Ym}{ho}$ increases, and as such the value of Xm decreases. Now we have the well known expression, $Xm = \frac{fm}{fc}$ where fm is the maximum usable frequency and fc is the critical frequency.

As the value of Xm decreases, fm which is equal to Xm fc, decreases; as fc (In other words, the electronic density in the inosphere) does not usually increase to the extent as to counterbalance the effect of thermal expansion of the layer. Thus it is clear that 19 metre band which was received prior to the cessation of signals indicated above, corresponded to the maximum usable frequency for transmission in the beginning, but later due to thermal expansion of the layer as discussed above, the frequency of transmission became greater than the maximum usable frequency between Delhi and Banaras and therefore the signals disappeared. Later with the advance of the day when the electronic density increased sufficiently, the maximum usable frequency increased and consequently the signal appeared again.

IV. ENHANCEMENT OF INTENSITY OF RECEIVED RADIO-SIGNAL PRIOR TO ITS DISAPPEARANCE

The intensity of the received radio-signal increases prior to its cessation as mentioned before and indicated in figs. 3, 4 and 5. Such enhancement of the signal has also been observed by Appleton and Beynon (4). The probable causes for such enhancement of intensity are discussed below.

IV (a) It will be seen from (p′,x) curves shown in figs. 6-12 that when the electronic density in the ionosphere is gradually decreased, the reflection is confined to the lower and upper extra-ordinary rays which produce interference patterns of periodic nature. As the electronic density is still further decreased, the path difference between the lower and the upper extra-ordinary rays is very much reduced and consequently the resultant intensity of the received radio-signal is considerably enhanced before the signal disappears due to the inadequacy of electrons.

IV (b) As the above phenomenon is associated with limiting frequency of reception, which in turn, is associated with the minimum distance of reception, another factor likely to contribute to such enhancement of signal intensity before the disappearance of the signal, is given below.

For the plane earth and thick ionospheric layer, the minimum distance of reception can be calculated from the expression for distance S between the transmitter and the receiver, given by,

$$S = \frac{tk}{2} \operatorname{Cos}\theta \log_e \frac{1+k \sin\theta}{1-k \sin\theta} + 2h \cot\theta.$$

where t = thickness of the ionospheric layer

h = the height of the lower boundary of the layer

θ = angle of radiation at the transmitter

and k = m. u. f. (maximum usable frequency) factor

Fig. 13 shows the delineation of curves drawn from the above equation, indicating the variation of distance between transmitter and receiver with the angle of radiation, computed for various values of m. u. f. factors. The upward bend of the curve after attaining the minimum distance between transmitter and the receiver, indicates that the reflection from the ionosphere does not abruptly disappear as the angle of radiation is increased to the value corresponding to the minimum distance of reception, but the reflection continues for a small range of angle beyond this value. For practical purposes, the radiation of energy within this small range of angle will be reflected back from the ionosphere, and the received signal will be confined within a narrow space beyond the minimum distance of reception. Consequently there will

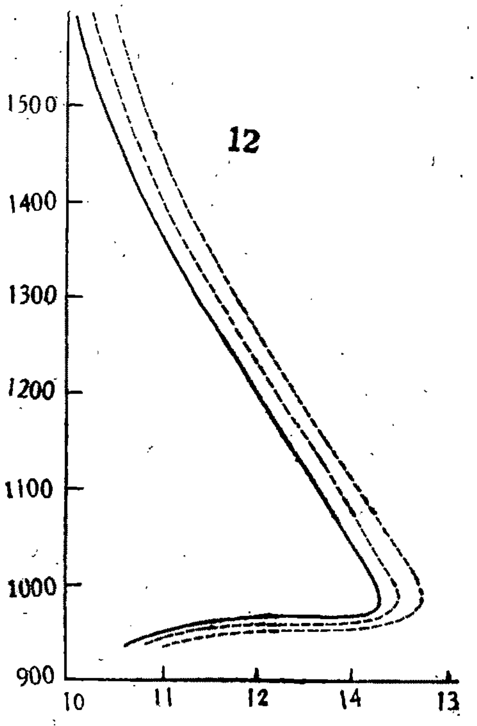

Fig. 12. Curves for $x=\frac{fo}{fc}$ or $\frac{fe}{fc}$. Continuous line fo. Right broken curve fe, H=·4; middle broken curve fe, H=·2.

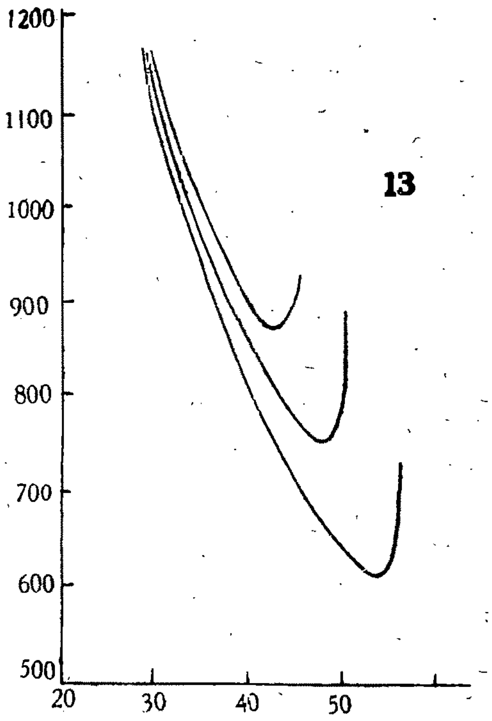

Fig. 13. Curves for signal of radiation degrees (horizontal) and distance between transmitter & receiver in kilometres ·(vertical) upper curve K=1·4, middle curve K=1·3 and bottom curve K=1·2.

be an enhancement of the intensity of received signal before its disappearance.

V. MAGNETO-IONIC (SLOW AND SMOOTH) PERIODIC FADING IN RELATION TO THE VARIATION OF THICKNESS OF IONOSPHERIC LAYER

The thickness of the ionospheric layer is found to affect the magnetic-ionic fading of radio-signals considerably as will be evident from the discussion given below.

V (a) It will be seen from the (p′,x) curves given in figs. 6—11, drawn for various values of the thickness of the ionospheric layer that with thinner layers, there is greater chance of reflection of wave as the m. u. f. factor for thin ionospheric layer is comparatively greater. With the increase of ionospheric thickness, the value of x decreases, resulting in preventing the chance of reflection of the wave, which was received in the case of thin layers. It will be clear from the figs. referred to above, that in the case of curves in fig. 6 for Ym = 10 km, the value of m. u. f. factor is nearly 1.42, while in the curves in figs. 7, 8 for Ym = 30 and 60 km, the values of m. u. f. factors are about 1.34 and 1.24 respectively. Thus thinner layers are comparatively more conducive to the reception of signals, and also the duration for appearance of the magneto-ionic fading is consequently longer.

V (b) It will appear from the comparative study of the curves for various thicknesses of ionospheric layers, that the path difference between the lower and upper rays, is smaller in the case of curves for the thinner layers than in the curves for comparatively thick layers and therefore the intensity of the magneto-ionic fading will be greater in the former case than in the latter as with smaller path travelled through the ionosphere, the absorption of energy is less.

VI. THE EFFECT OF VARIATION OF MAGNETIC FIELD ON THE SLOW AND SMOOTH PERIODIC (MAGNETO-IONIC) FADING

The (p′, x) curves have been drawn for two values of magnetic field. Figs. 6-8 show the curves for H = 0.2 Gauss which is approximately the value of the magnetic field in the F2-region over India and figs. 9-11 for H = 0.4 Gauss which is the corresponding value in the F2-region over England. Fig. 12 indicates the effect of magnetic field for H = 0.2 and H = 0.4 Gauss side by side on an extended time scale, as mentioned before. It will be evident from these curves that greater the magnetic field, greater the separation between the ordinary and extra-ordinary components of the split waves. This leads to the conclusion that where the magnetic field is smaller, the magneto-ionic fading will be slower in comparison with that obtained at places of greater magnetic field; as in the former case, the path difference between the interfering components is less than in the latter.

VII. VARIATION IN THE NATURE OF MAGNETO-IONIC FADING WITH GEOGRAPHICAL AND MAGNETIC LATITUDES

At low geographical latitudes, the ionospheric layers are comparatively thicker than at higher latitudes due to thermal expansion of the layer (6-12) and therefore at lower latitude, the duration of the magneto-ionic fading will be comparatively small, intensity lower, and frequency large.

Further, as at lower magnetic latitudes, the separation between the split-components of the wave due to magneto-ionic effect will be less than at higher latitudes, consequently the magneto-ionic fading obtained at places of lower magnetic latitude, will be comparatively slower than those obtained at places of higher latitudes. Thus it will be seen that the variation of magneto-ionic fading pattern with geographical latitude will be in the opposite sense to the variation of the fading pattern, with magnetic latitude for the same distance between the transmitter and receiver.

VIII. CONCLUSION

The theory of formation of magneto-ionic (slow and smooth) periodic fading has been briefly mentioned. The electronic density in the F2-region of the ionosphere referred for such fading patterns on a particular frequency has been discussed. Factors leading to the evening and temporary morning disappearance of the signals have been analysed. How the varying thickness of the ionospheric layer affects the shaping of magneto-ionic fading, has been described. The probable causes for the enhancement of intensity of received radio-signals prior to cessation have been mentioned. Variation of magnetic field in relation to slow and smooth periodic fading has been illustrated. Lastly the effects of geographical and magnetic latitudes on the nature of magneto-ionic fading has been shown. It may be concluded that each section of this paper has been devoted to reveal some information or the other of the ionospheric layer as suggested by the various phenomena associated with the slow and smooth (magneto-ionic) periodic fading patterns of the received radio-signals.

IX. ACKNOWLEDGMENTS

The author has great pleasure in recording his feelings of gratitude to Dr. S. S. Benerji D. Sc. Engineering College B. H. U., Banaras for his supervision, suggestions and healthy criticism. Thanks are due to Prof. G. C. Mukerji, Vice-Principal Engineering College, B. H. U., for his ever helpful attitude towards the author. Lastly he owes a good deal to Dr. R. K. Singh, D. Ed. (Harvard), Principal, B. R. College, Agra, who has always encouraged him for research and advanced studies.

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ULTRA HIGH FREQUENCIES

By B. N. Srivastava, *Lecturer in Physics, Bareilly College, Bareilly.*

Ordinary triode and pentode valves cannot be used with any degree of success at the frequencies of micro-waves due to their large interelectrode capacity, lead inductance and electron transit time.

I therefore employed arcon tubes designed mainly for these frequencies for the oscillator. The acorn tubes used are 6J6 and 955, twin triodes and simple triode respectively. Two 6J6 tubes were arranged in push-pull parallel circuit to increase power output. The base of the tubes was removed in order to reduce the additional capacitance and dielectric losses contributed by them. The resonant circuit is simply made of two parallel thick wires separated by 1.5 cm from each other, provided with a short strip sliding over the parallel wires. The sliding strip is helpful in tuning the transmission line to a particular desired frequency (Fig:1). The transmitter could be operated at 15 watts input and is capable of delivering 2 watts output within

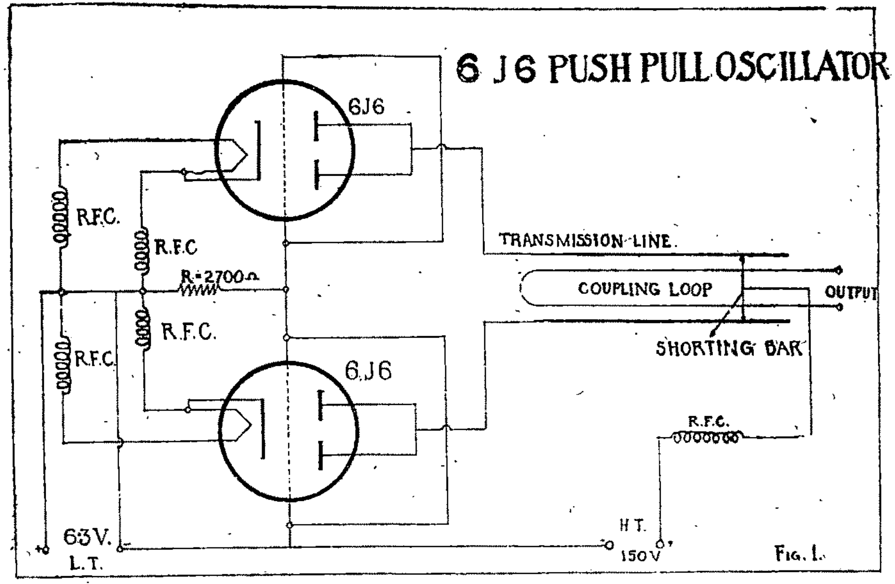

6 J6 PUSH PULL OSCILLATOR

Fig. 1.

the range of 300 Mc to 450 Mc the output dropping off slightly towards 450 Mc end of the band.

After costructing the 6J6 push-pull oscillator, my next objective was to calibrate its transmission line. From our previous experience we know that the frequency metres used for ordinary radio work are not suitable, as they absorb an appreciable amount of power from the source. I therefore took the help of the lecher wire method with a glow lamp as detector. The lecher wire was coupled to the transmission line. As I have stated above, the power output is 2 watts and therefore it is enough to light a torch bulb if placed on the lecher wire. As the lecher wire however maintains stationary waves over it, there will be voltage and current nodes and antinodes respectively situated at quarter wave-lengths. These positions can very easily be detected from the intense glow of the lamp at the current antinodes. If the glow lamp and another shorting bridge is used along with that, a very sharp result is obtained. The lamp is first placed at the maximum glow position nearest to the coupling loop. The shorting bridge is then placed close to the lamp and taken away from it gradually. At certain sharp points separated by half wave length distance the glow became suddenly very bright. From these maximum glow positions the wave length is accurately checked for different lengths of the transmission line.

The following observations and the graph plotted from the values give the details of frequencies for various lengths of the transmission line.

TABLE 1.

Length of the transmission line	*Corresponding frequencies*
6·5. cms.	265.5 Mc.
5.5. cms.	294.1 Mc.
5.0. cms.	306.1 Mc.
4.0. cms.	326.1 Mc.
3.0. cms.	345.0 Mc.
2.5. cms.	366.0 Mc.
2.0. cms.	380.0 Mc.
0.5. cms.	429.0 Mc.

The maxima in the above observations were virtually judged to a great approximation by only visual distinction. This may sometimes introduce serious error. Therefore in order to be more precise in measurements, the valve voltmeter was employed for detection of the potential variations along the lecher wires, which could be directly read in the milliammeter put in the anode circuit. A slight variation in the voltage along the lecher wires can be indicated fully by the change in the plate current. I constructed three valve voltmeters using PM. 2, 955 and IN5GT tubes in each case but the one using IN5GT tube was found much more efficient than the other two (Fig. 2).

The input for the valve voltmeter is taken from the two consecutive points of the lecher wire, which is previously coupled to the transmitter. The shorting bridge is moved gradually away from the valve voltmeter input leads and the corresponding anode current was recorded. At all such points there is voltage antinode, maximum anode current is recorded in the valve voltmeter.

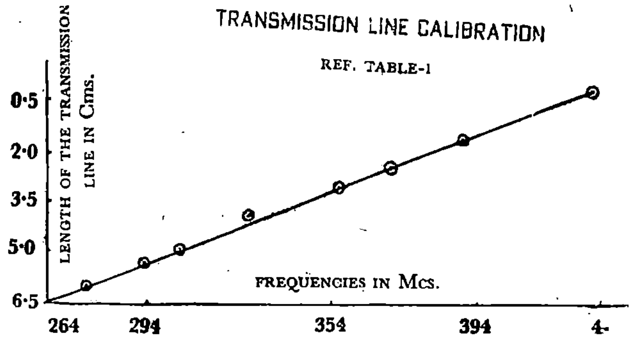
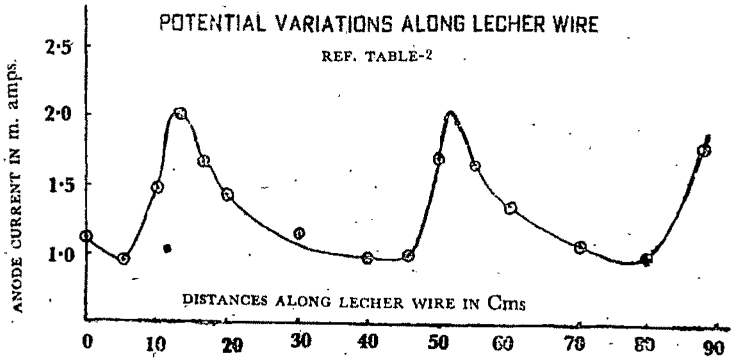


TABLE 2.

Transmission line ... *2 cms.*
Anode voltage of 626 oscillator ... *140 Volts*

dist. of bridge from input leads on lecher wires in cms.	*m. ammeter readings in valve voltmeter. in m. amps.*
0	1.2
5	0.8
15	1.6
20	4.3
23	5.35
25	4.1
30	2.3
35	1.45
40	1.1
45	0.8
55	1.3
60	2.8
65	4.75
70	2.7
75	1.3
88	0.8

From serveral such observations for different lengths of transmission line, the corresponding wave-lengths were thus determined for various resonant frequencies very accurately. It was found that as the length of the transmission line was successively decreased, the output of the transmitter became feebler and feebler and the positions of the nodes and antinodes on it could not be detected even with valve voltmeter. The minimum detectable wave-length in this way was found to be 70 cms corresponding to 0.5 cms length of the transmission line.



Another very important property of these waves investigated during these experiments showed that if the length of the leads joining the lecher wire points to the valve voltmeter was increased, the current in the anode circuit of the valve voltmeter is reduced to a great extent, indicating thereby that the leads absorb sufficient power at this stage of frequencies.

Further progress towards lower wave-lengths was not possible with this oscillator. I therefore constructed another oscillator with 955 acorn tube, using a single tube in a Hartley's circuit. The power of this transmitter was too feeble and minimum available wave-length was 60 cms or frequency 500 Mc.

As no other tubes were available and also klystrons or magnetrons could not be procured, I changed the line of work at this stage and performed some very interesting experiments with the help of a suitable receiver which I constructed for this purpose. This receiver was suitable for those band of frequencies which our transmitter could supply. The circuit of this regenerative type of receiver is shown in the figure 3.

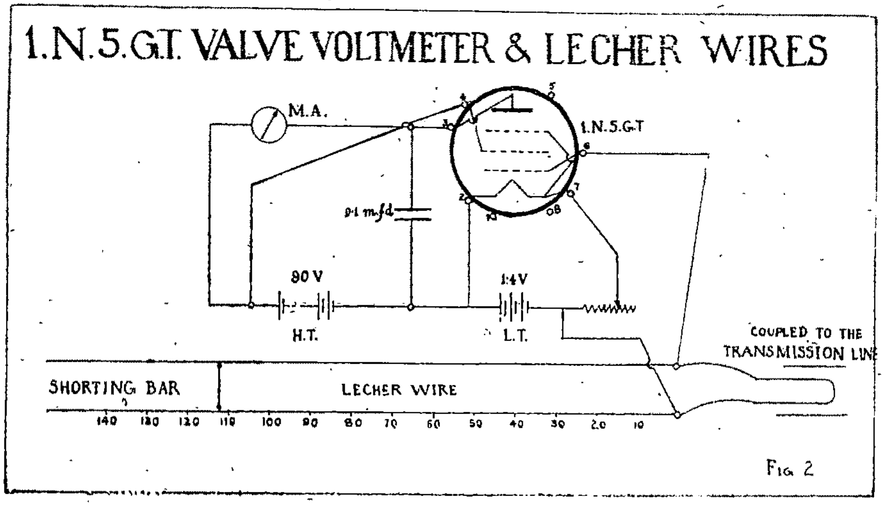


Fig. 2

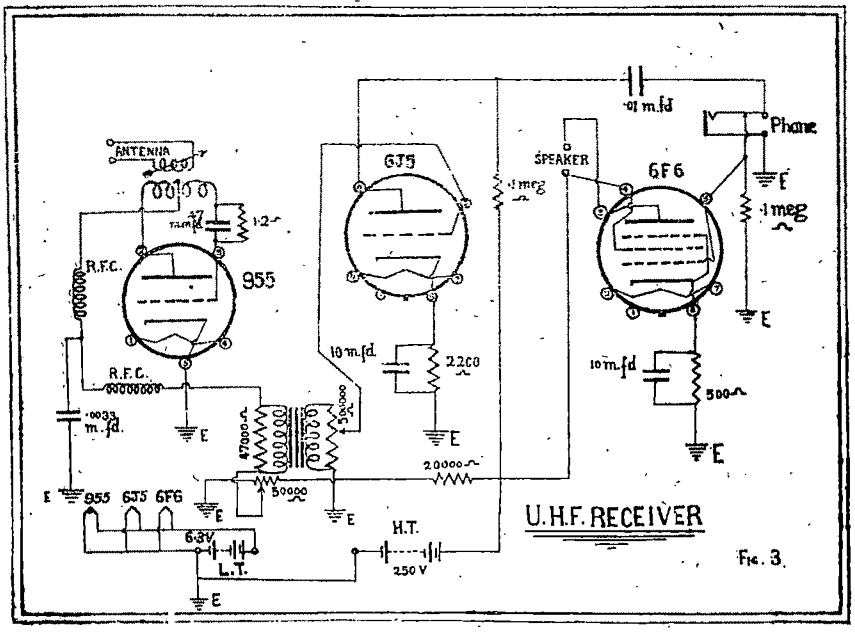


Fig. 3.

For my present work I constructed two suitable quarter wave antennae of calculated length. These antennae possess directive properties in the horizontal direction if kept vertical.

The continuous wave oscillations of the 6J6 push-pull oscillator were modulated by means of a buzzer interrupting the direct current from a 6 volts battery 50 times per second. This modulated signal was radiated by the trasmitter antenna which was tuned suitably to a particular frequency. The receiver head phone kept at a distance was found to respond to these signals regularly when the object of transmission and reception of signals at these frequencies was achieved.

INTERFERENCE EXPERIMENT

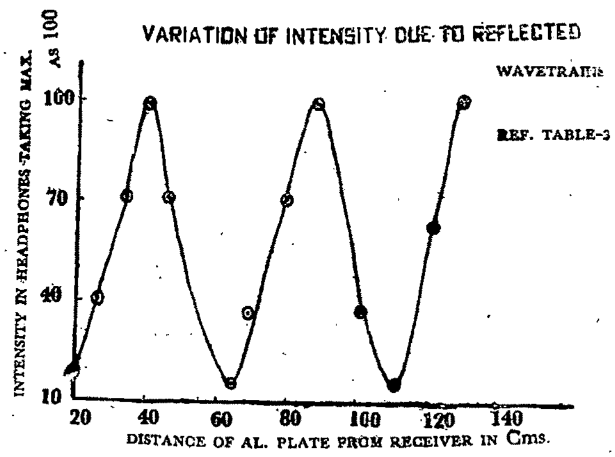
A suitable experiment was devised analogous to the interference experiments in sound to illustrate the destructive interference phenomenon of these waves. An aluminium plate of 1½ metres square was taken and placed at a distance from the transmitter antenna. The waves proceeding in the direction of the plate are reflected back and thus a train of stationary waves having maximum and minimum vibrational positions are produced in space between the aluminium plate and the transmitter antenna. When the receiver antenna is moved from the plate towards the transmitter, maxima and minima of the intensity in the headphones are recorded at fixed distances from the aluminium.

TABLE 3.

Position of Al. plate from receiver antenna.	*Sound intensity as computed from Max. as 100.*
25.5 cms.	40%
33.0 cms.	70%
41.5 cms.	100%
50.0 cms.	70%
57.0 cms.	40%
66.0 cms.	20%
73.0 cms.	40%
80.5 cms.	70%
87.5 cms.	100%
96.5 cms.	70%
103.5 cms.	40%
111.5 cms.	20%
121.0 cms.	60%
130.5 cms.	100%

A graph showing the distance of aluminium plate from the receiver antenna and the percentage of sound intensity is given. The above experiment was performed with the receiver and transmitter completely shielded to avoid unnecessary reflections from the surrounding objects. To our expectations these distances of maximum intensity were found at approximately half wave-lengths of the transmitted wave-length.

After this experiment, I wanted to study the polarisation of these e.m. waves. A frame-work of wire gratings was constructed, in which there were parallel wires about 2 mm diameter placed at equal distances. This frame-work of wires was placed vertically in between the transmitter and receiver antennae and was rotated about a horizontal axis. A marked reduction of intensity in the head-phones is recorded when the grating wires are horizontal. Similarly an edge diffraction experiment was arranged with a large aluminium plate obstacle in the path of the transmitted waves. At two points in the vertical direction the sound in the receiver headphone was recorded to be reduced.



These interesting experiments confirm that the electromagnetic radiations are analogous in their optical properties to visible light. It was also found during the course of these experiments that the circuits at this stage of frequencies are very simple and avoid the complications of high, medium, and low frequency circuits. Due to this simplicity in circuits and a wide range of bands of frequencies and their limited range these waves can replace the present crude and out of date means of communications in railways, post-offices and other business concerns with greater economy and efficiency. In the scientific sphere these waves are opening new field of research and investigation in different branches of Physics.

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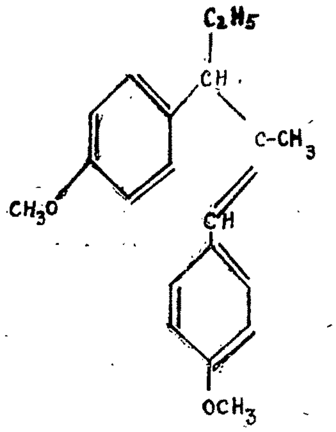
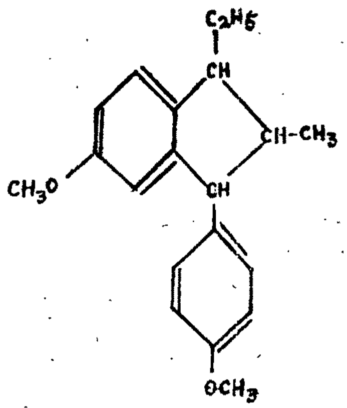
SATURATED DIMERS OF PROPENYL PHENOL ETHERS

By G. N. HAKSAR, M. Sc., Ph. D. (Bristol), *Department of Chemistry, Victoria College, Gwalior.*

A number of propenyl phenol ethers are known to dimerise under the influence of acids. For example, anethole gives rise to *iso*anethole and metanethole simultaneously, and other well-known instances are the dimerisatiron of *iso*eugenol to di-*iso*eugenel methyl *iso*eugenol to di-methyl*iso*-eugenol or di-*iso*homogenol, and *iso*safrole to di-*iso*safrole. Among the less known cases, asaron (5-propenyl-1:2:4-dimethoxybenzene) and *iso*apiole (5-5propenyl-1:4-dimethoxy-2:3-methylenedioxy benzene) give di-asaron and di-*iso*apiole respectively (25).

It is to be expected, therefore, that all these dimers should have the same type of structure, since the propenyl side-chain is common to all these phenol ethers and this should be the deciding factor in the process of dimerisation. However, two classes are generally exemplified, one by *iso*anethole (I) and the other by metane-thole (II) which is saturated.

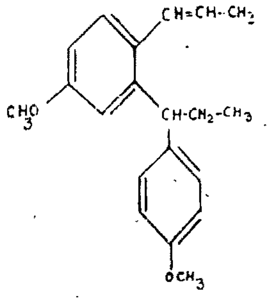


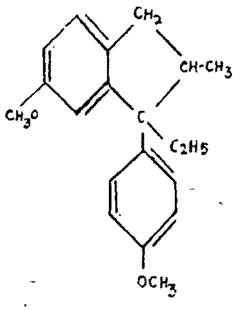


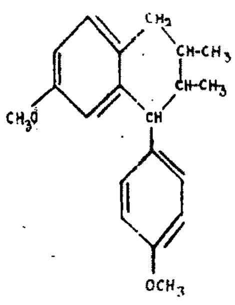
The more commonly formed dimeric propenyl compounds are saturated and these substances were for long thought to be derivatives of either *cyclo*-butane or 9:10-dihydro-anthracene.

Dimers of anethole.—Goodall and Haworthe (11) showed that anethole undergoes dimerisation, under the influence of hydrogen chloride, to give *iso*anethole, the structure of which they established as (I). Although metanethole was prepared by Gerhardt (12), very little was known about its structure because it was not available in reasonable yields. Baker and Enderby (2) devised a simple process for dimerising anethole by refluxing it with 43% sulphuric acid and obtained liquid *iso*onethole (about 70% yield) and metanethole (24%yield). They also found that *iso*anethole could be converted into metanethole by the action of stannic chloride in chloroform. A. muller *et. al.* (18) have effected this conversion by using titanium tetrachloride. It may take place slowly at room temperature, probably under the influence of traces of acid (22). It is also very probable that the metanethole isolated from a species of sponge by Bergmann and McAleer (4) may be an artifact derived from anethole.

In accordance with theoretical expectations and experimental evidence, Baker and Enderby (*loc. cit.*) postulated metanethole to be 6-methoxy- -(p-methoxyphenyl)-2-methyl-3-ethyl hydrindene (II). Since in the simultaneous formation of *iso*anethole and metanethole, it was found that the yield of metanethole was never more than 24%, regardless of the time of refluxing, it was concluded that the latter does not arise from the former, but probably from the intermediate (III). This suggested two more probable structures (IV) and (V) for metanethole. The tetrahydronaphthalene structure (V), being related to the natural lignans, was quite attractive, but it had to be rejected because metanethole could not be dehydrogenated to a naphthalene derivative, and moreover, it in-







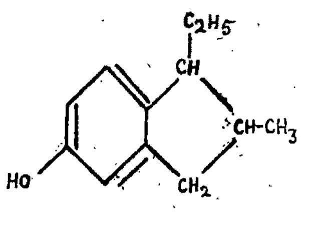
volved a $\beta\beta'$ linking of the side-chains. It is more natural to assume an $\alpha\beta'$ linking of the side chains, such as occurs in the polymerisation of styrene and in *iso*anethole. Yoshida and Watanabc (31), have studied the dimerisation of an-ethole in "deuteriated" hydrochloric acid and concluded that the mechanism was similar to that in the case of styrene, Dimeric styrene (24) and dimeric p-*iso*propenyl toluene (14) are known to be substituted phenylydrindenes. The earlier work on dimerides of substituted ethylenes has been summarized by Bergmann and Weiss (5). Again, structure (II) for metanethole is more probable than structure (IV), because in the ring-closure from (III) to (IV) the unlikely addition of a proton to the more weakly anionoid of the two ethylenic carbon atoms would be involved.

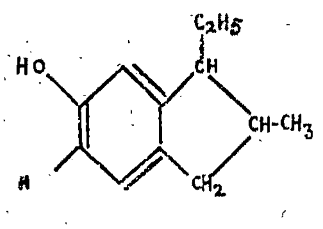
The hydrindens structure for metanethole, as postulated by Baker and Enderby, has now attained a unique importance, and all other saturated dimers of propenyl phenol ethers have now been assigned a similar structure. Subsequent investigations mainly by A. Müller and his collaborators (16) and also by van der Zanden and de Vries (29) have provided additional evidence of the accuracy of this formula. Stepwise synthesis of metanethole was carried out by van der Zanden and de Vries (*loc. cit.*) and by A. Müller *et al.* and they reported a stereo-isomer of (II), m. p. 99° instead of 135° (four racemates are possible for metanethole). Recently, however, van der Zanden and de Vries (30) have succeeded in synthesising metanethole itself, m. p. 134-134.5°. *Structures of di-iso-eugenol and di-methyl isoeugenol.*—Since the methylation of di-*iso*eugenol or the dimerisation of methyl *iso*eugenol gives the same product, it is evident that both di-*iso*eugenol and di-methyl*iso*eugenol (di-*iso*homogenol) have the same type of structure. Haworth and Mavin (13) suggested the dibydroanthracene structure for di-*iso*eugenol, while Szeki and co-workers adhered to the *cyclo*butane structure. However, A. Müller and co-workers (16) who first proposed the lignan structure, later abandoned this in favour of the hydrindene structure. This was accepted by Cartwright and Haworth (7) and further confirmed by A. Müller and Horvath (17) and von Doering and Berson (9).

It is interesting to note that E. Funakubo *et al.* (10) obtained the di-methyl ether of di-*iso*chavibetol by the action of methyl sulphate and mention the isolation of two forms melting at (i) 105.5-106.5° and (II) 94-96°, and a third form melting at 10-10°, obtained from methyl *iso*chavibetol, after keeping for 190 days. The details of the paper are not available, and it is not known whether mixed melting points were taken with di-methyl*iso*eugenol, which is also known to give different forms with similar melting points. Since only the positions of the hydroxyl and methoxyl groups are interchanged in *iso*chavibetol and *iso*eugenol, di-methyl *iso*chavibetol must be identical with di-methyl *iso*eugenol.

Structure of di-isosafrole.—Two crystallime forms of di-*iso*safrole are definitely known having melting points 95° and 145°. The lower melting form could be converted into the higher melting form by heating for a few hours at 150° (15). A *cyclo*butane structure was proposed by E. Puxeddu while Robinson (23) regarded it as dihydro-anthracene derivative. E. Takebayashi (27) studied the formation of these two forms of di-*iso*safrole and found that an oily substance was also formed. Takebayashi and Yamada (28) concluded, from a study of absorption spectra and chemical reactions, that no ethylenic bonds existed in these compounds and they were the *cyclo*butane type in their stereochemical relation to each other. Pailer obtained the liquid dimeride and from a study of its oxidation products established its structure as of the unsaturated type related to *iso*anethole. In a more recent paper, Pailer *et al.* have suggested a hydrindene structure, related to metanothole, for the saturated crystalline dimer of *iso*safrole, m. p. 146°.

Further evidence for the hydrindene structure.—The more recent work of Pailer has completely established the hydrindene structure for mesanethole, di-*iso*eugenol and its dimethyl ether, and di-*iso*safrole. By the action of hydriodic acid and red phosphorus, they have succeeded in splitting of the 1-phenyl group and have obtained phenol and 2-methyl-3-ethyl-6-hydroxydrindene (VI) from

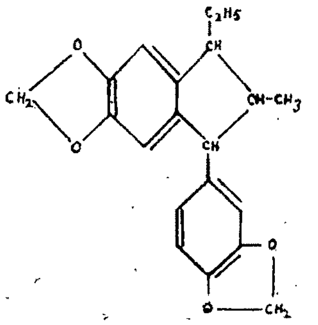


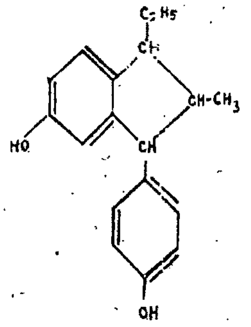


metanethole, and catechol and 2-methyl-3-ethyl 5:6 dihydroxydrinene (VII) from dimethyl *iso*eugenol. They demethylenated di-*iso*-safrole, using a dry Grignard reagent, and by further reductive degradation obtained catechol and the dihroxyhydrindene (VII). They have also synthesised these hydroxyhydrindenes and found that the synthetic compounds are identical with those obtained by degradation. Since the same dihydroxyhydrindene (VII) was obtained from di-methyl *iso*eugenol and di-*iso*safrole (m. p. 145°) it is very probable that both these compounds have the same stereochemical configuration. This hydrindene structure still contains two asymmetric carbon atoms in the molecule and since the synthetic material is identical with the products of degradation, the positions of the different groups about carbon atoms 2- and 3- are undoubtedly fixed. The only possibility of stereo-isomerism could be at position 1.

Stereochemical correlation of dimers.—From a consideration of the partial correlation between di-methyl *iso*engenol and di-*iso*safrole as obtained by Pailer *et al.* it appeared that the dimerisation of aryl proprenyl derivatives to give saturated compounds would give in all cases the same stereo-isomeride of 1-phenyl -2-merhyl -3-ethylhydrindene, bearing the appropriate unclear substituents. It, therefore, became of importance to attempt the conversion of metanethole into di-methyl *iso*eugenol by introducing two methoxyl groups into the molecule. This has now been achieved by Baker, Haksar, McOmie and Ullbricht.

A double Friedel-Crafts reaction was carried out on metanethole in ether using acetyl chloride in presence of a very large excess of aluminium chloride. Simultaneous demethylation also

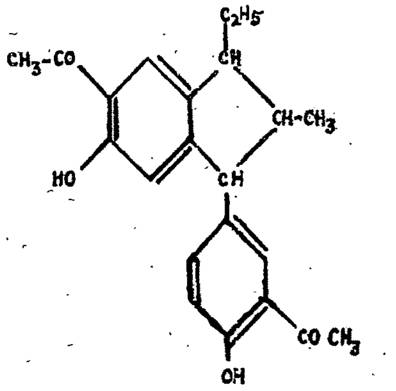


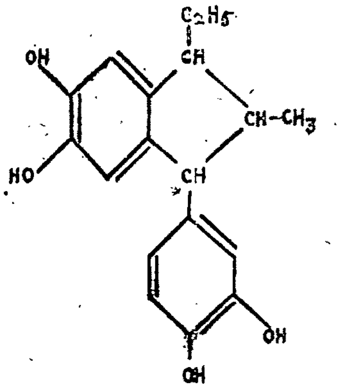


took place and the dihydroxy-diketetone (VIII) was formed. This process of nuclear acetylation is incidentally of some interest on account of the positions taken up by the acctyl groups. Positions 3'- and 5'- of the 1-phenyl group are identical, but the second acetyl group could have entered the mucleus in position 5. The former postibility was excluded on account of steric effects. The substitution of the acetyl group in position 5 affords another experimental evidence of the reality of the Mills-Nixon Effect, in which a double bond is fixed at position 5 and 6 in hydrine. However, the assumption on which the Mills-Nixon Effect was based is untenable now (1).

The diketone (VIII) was then converted into the terahydroxy compound (IX) by a Dakin oxidation. This product could not be successfully purified. On methylation, the corresponding tetramethyl ether was obtained, m.p. 94-96°. The mixed melting point of this tetramethyl, ether with an authentic specimen of di-methyl *iso*eugonol, m. p. 95-96, showed no depression. The identity was further proved by X-ray powder photograph which showed exact correspondence of all lines (over twenty) in both position and intensity. This racemic di-methyl *iso*eugenol seems to be dimorphic, because slow crystallisation from methanol gives a product, m.p. 105-106° which falls after several weeks to 95-96°. The lower melting form is also obtained by rapid crystallisation from concentrated solution (20,8).

Attempts were then made to extend this correlation to di-isosafrole by methylenation of the tetrahydroxy compound (IX), but they were not successful. Another approach to this problem has, therefore, been thought of. Sodium in liquid ammonia de-alkylates a number of alkyl oryl ethers, the ease of reaction depending upon the substitution of both groups. Several catechol and methylene dixybenzes lose an oxygen from the nucleus giving phenol or its derivatives (6). A similar fission of methylene-dixy ring has been observed by D. Papa *et. al.* (21) when using Reney's alloy and aqueous alkali. From di-*iso*safrole (X), therefore, we expect to obtain "metanethol" (XI) which a methylation would give metanethole. The results of this





investigation will be published later.

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DESCRIPTION OF A NEW CHALCID PARASITE OF MIDGE OF ECHINATE GALL OF MANGO LEAF.[1]

By CHANDY KURIAN, M. Sc., F. R. E. S., *Research Associate, School of Entomology, St. John's College, Agra.*

Professor M. S. Mani reared several examples of a new species of *Neomegastigmus* Girault[2] as a parasite of the midge *Amradiplosis echinogalliperda* Mani[3] from the echinate gall (Gall No. 196) on leaf of *Mangifera indica* Linn., recently collected by me from the New Forest, Dehra Dun. The type and other specimens are retained for the time being in the collections of the School of Entomology.

I thank Dr. M. S. Mani, Professor of Zoology and Entomology, for placing this material at my disposal and for guidance.

Superfamily CHALCIDOIDEA

Family *TORYMIDAE*

Subfamily Megastigminae

Neomegastigmus amraeus, sp. nov.

Female.—Length 2.5 mm. Colour reddish-brown. Head reddish-brown; viewed from above length two-fifths the breadth; interorbital distance slightly over half the breadth of the head; post-orbital one-third the width of eye; eyes brick-red, bare; ocelli pink-red, arranged in a broad triangle; front ocellar slightly over half the interocellar which latter is very slightly more than twice the ocellocular; vertex smooth and shiny, with few black setae scattered, distinctly irregularly margined, the margins nearly touching the posterior ocelli; occiput

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[1] Contribution No. 31 from the School of Entomology, St. John's College, Agra, published with the permission of the Professor of Zoology and Entomology.

[2] GIRAULT, A. A. 1915. *Mem. Queensland Mus.*, **4:** 294.

[3] MANI, M. S. 1952. *Agra Unv. J. Res.*, **1:** 50.

irregularly longitudinally carinate; viewed in front (Fig. 5) length three-fourths the breadth; interorbital distance slightly more than half the breadth of the head; length of eye twice that of gena and three and a half times the post-orbital distance; frons and face transversely rugoso-coriaceously sculptured, with few fairly long dark setae scattered irregularly; clypeus nearly truncate, slightly darker than the rest of face, with somewhat irregular coriaceous sculpture; mandibles tridentate on either side, first tooth acute, the rest blunt, same colour as rest of head except the dark reddish-brown teeth. Antenna light reddish-brown, apex very slightly darker, inserted nearly on the middle of face, above an imaginary line joining the lower orbital borders; scape thrice the pedicel, which latter is slightly over four times the ring-joint; first funicular one-third the scape and nearly equal to the pedicel; second and remaining funicular segments subequal and are equal to first except the last funicular which is only six-sevenths the first; club-joints together nearly four-fifths the scape and equal to ring-joint, first and second funicular segments combined; the first two club-joints are nearly equal and the last is seven-eighths the penultimate (Fig. 3). Thorax: Reddish-brown, except dark reddish-brown metathorax and anterior part of propodeum; length one and two-thirds the breadth at the region of the tegulae; prothorax nearly two-fifths the whole length of thorax, nearly smooth and shiny except for transverse coriaceous striations; mesothorax slightly shorter than prothorax, anteriorly roughly transversely coriaceously sculptured, posteriorly with few transverse rows of tubercular wart-like processes; parapsidal furrows deep, distinct and complete; scutellum nearly as long as mesonotum, convex, roughly rugoso-coriaceously sculptured; axillae large and prominent; metathorax nearly one-fifth the scutellum, somewhat smooth and shiny, with three distinct foveae on either side; propodeum nearly three-fourths the scutellum, with a median longitudinal and a few lateral irregular longitudinal carinae some of which do not reach the posterior end; sculpture indistinctly rugoso-reticulate, with a few long silvery-white pubescence laterally; propodeal spiracles medium-sized and round. Legs reddish-brown. Fore coxa two and one-fourth the trochanter, which latter is nearly one-fourth the femur; tibia very slightly less than or nearly equal to femur; tibial spur slightly less than one-fourth the tibia and a little less than the metatarsus; metatarsus one-fourth the tibia and one-third the rest of tarsi combined. Mid coxa nearly one and a half times the trochanter ; femur four times the trochanter; tibia one and one-fourth the femur; tibial spur one-seventh the tibia and three-fourths the metatarsus; metatarsus slightly less than one-fifth the tibia and slightly more than one-third the rest of tarsi combined. Hind coxa two and one-fourth the trochanter; femur three and a half times the trochanter, laterally with one or two distinct rows of setae; tibia one and one-fourth the femur; tibial spur one-seventh the tibia and five-eighths the metatarsus; metatarsus one-fourth the tibia and slightly less than half the rest of tarsi combined (Fig. 4). Fore wing length very slightly less than two and a half times the breadth; submarginal nearly two and one-third the marginal, which latter is equal to the post-marginal and slightly less than twice the stigmal (Figs. 1 & 2). Abdomen reddish-brown, petiolate, petiole short; nearly one and one-fourth the whole length of thorax; somewhat dorsally arched, laterally compressed; tergites smooth and shiny; four tergites distinctly visible, the first the largest, rest of them being subequal and are nearly three-fourths the first ; ovipositor somewhat longer than abdomen, issued ventrally anteriorly; ovipositor sheath equally long.

Male.—Length 2.0 mm. Colour reddish-brown. Head viewed from above length slightly less than half the breadth; interorbital distance slightly less than two-thirds the breadth of the head; post-orbital one-third the width of eye; vertex margined, nearly smooth and shiny, with few irregularly scattered black setae; occiput smooth and shiny, except for extremely fine and faint longitudinal striations; ocelli reddish-brown with a black inner rim surrounding them; inter-ocellar distance one-third the ocellocular which latter is three-fourths the front ocellar; eyes brick-red, bare; frons nearly smooth and shiny except for a few faint longitudinal carinae laterally, which portion bears also a few long black setae; face transversely rugoso-coriaceously sculptured with a few scattered black setae; viewed in front (Fig. 6) length four-fifths the breadth of head; interorbital distance nearly three-fifths the breadth of head; length of eye twice that of gena and thrice the post-orbital distance; clypeus same sculpture as face, but fainter; mandibles concolouress with the rest of face, tooth darker, tridentate on either side, the first tooth acute, the rest blunt. Antenna light reddish-brown, apex slightly darker, inserted on the middle of face, above an imaginary line joining the lower orbital borders; 13-segmented; scape, pedicel, ring-joint, 7-segmented funicle and triarticulate club; scape two and a half times the pedicel, which latter is slightly over thrice the ring-joint; first funicular thrice the ring-joint and slightly shorter than the pedicel; second funicular equal to first; funicular segments third to seventh subequal, very slightly longer or nearly equal to second; club-joints together four-fifths the scape, twice the pedicel and

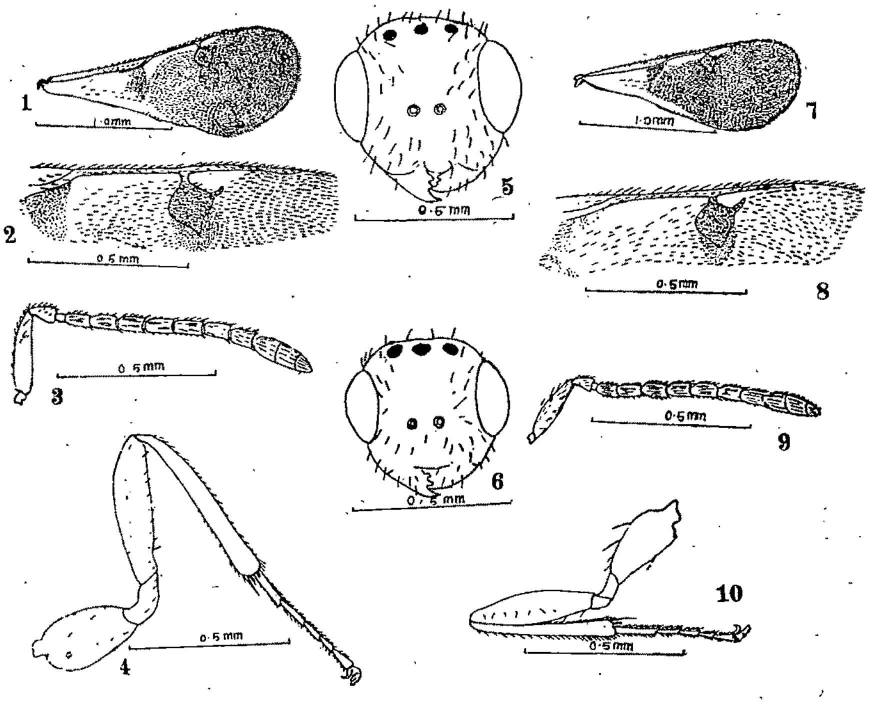

Fig. 1—5. *Neomegatsgmus amraeus*, sp. nov. Female. 1. fore wing, 2. stigma of fore wing enlarged, 3 antenna, 4. hind leg, 5. head viewed in front.

Fig. 6—10. *Neomegastigmus amraeus*, sp. nov. Male. 6. head viewed in front, 7. fore wing, 8. stigma of fore wing enlarged, 9. antenna, 10. hind leg.

equal to ring-joint, first and second funicular segments combined; first club joint three-fourths the last funicular, second slightly longer than the first and the third slightly shorter than the first. Throax reddish-brown except the darker metathorax and anterior half of the propodeum; length slightly over one and three-fourths the breadth; prothorax slightly less than one-third the whole length of thorax, faintly transversely coriaceously sculptured with a few scattered black setae and with a fine transverse carina about one-third of the distance from the anterior margin; mesothorax nearly as long as prothorax, sculpture almost same as prothorax, but rougher; parapsidal furrows deep and complete; scutellum as long as mesothorax, roughly rugoso-carinately sculptured, giving a somewhat leathery appearance; metathorax one-sixth the scutellum, smooth and shiny; propodeum nearly three-fourths the scutellum, with a median longitudinal carina and a few incomplete, irregular, branching and nearly longitudinal carinae, giving an irregularly rugoso-reticulate appearance; a few silvery-white setae are found laterally; propodeal spiracles medium-sized and circular. Fore coxa two and four-fifths the trochanter; femur four times the trochanter; tibia equal to femur; tibial spur one-seventh the tibia; metatarsus one-fourth the tibia and one-third the rest of tarsi combined. Mid coxa nearly one and three-fourths the trochanter; femur four and a half times the trochanter; tibia one and one-fourth the femur; tibial spur slightly less than one-sixth the tibia; metatarsus one-fifth the tibia and two-fifths the rest of tarsi combined. Hind coxa two and a half times the trochanter, which latter is one-fourth the femur; femur laterally with one or two distinct rows of setae; tibia slightly longer than femur; tibial spur one-seventh the tibia and four-sevenths the metatarsus; metatarsus one-fourth the tibia and slightly less than half the rest of tarsi combined. Fore wing length somewhat less than two and a half times the breadth; submarginal very slightly more than twice the marginal which latter is slightly longer than the post-marginal and twice the stigmal. Abdomen slightly shorter than thorax, distinctly petiolate; petiole yellowish-brown; anterior part of abdomen somewhat laterally compressed, posterior dorsally depressed; five tergites distinctly visible; first the largest, much longer than the rest and cover half the abdomen; second one-fourth the first, the rest gradually become shorter; tergites smooth and shiny with a few scattered pale setae; male genitalia one-seventh the whole length of abdomen and exserted from ventral side far anterior to the apex.

Holotype female dissected on slide No. $\frac{939}{C}$; *allotype* male dissected on slide No. $\frac{939}{C}$; *paratypes* males and females in spirit, labelled: "Reared by M. S. Mani from echinate gall No. 196 on leaf of *Mangifera indica* Linn., collected from Dehra Dun, February 1953". This is the first record of the genus from India.

ON A COLLECTION OF PLANT GALLS AND GALL MIDGES FROM INDIA*

By M. S. MANI, M. A., D. Sc., F. Z. S. I., F. R. E. S., F. L. S., *Professor of Zoology, & Entomology, School of Entomology, St. John's College, Agra.*

With plates V—VII

The plant galls and gall midges described in this paper were mostly collected by me from various localities in India. Some of the examples were also received through the courtesy of friends. I am particularly indebted to Mr. S. Ramachandran, Retired Government Entomologist, Coimbatore, who has established a regional laboratory in his house and has successfully reared several unique species of gall midges from galls collected by his servant Mr R. Krishnan. Of particular interest are gall Nos. 466, 209, 456 and 453 ; gall No. 453 on *Acacia suma* Buch.-Ham. is perhaps the most bizarre example of a plant gall in my collection. Mr. Ramachandran's successful rearing of the midge causing the gall No. 456 on *Acacia suma* is of great importance.

The microtome sections of the galls described here were prepared by my Research Associate Mr. Santokh Singh. The photographs that illustrate the paper were taken by me with leica hektor 13.5 on Ilford HP3 and processed at 18° C.

A. DESCRIPTION OF GALLS

Natural Order MENISPERMACEAE

Cocculus hirsutus Diels

Gall No. 349 by an unknown midge on flowers.

Plate VIII

New gall. Irregular, subglobose, solid, fleshy, brown, indehiscent, lobulated and tubercled, densely and closely villous tumescence of entire staminate flowers, with the floral envelopes and stamens greatly swollen and fleshy and enclosing irregular, narrow, tortuous passages containing numerous red-coloured midge larvae. In the young gall the tips of the biseriate sepals are more or less unaltered and flat but swollen and greatly altered basally, especially in the outer series. The enormously swollen stamens often bear vestigial and empty anthers and are embraced by the intumescent and malformed petals. The entire flower is thus greatly deformed and transformed into a solid fleshy mass with irregular bulging lobes and larger or smaller fleshy pubescent tubercles on the surface. The epidermal cells disorganized, hypertrophied. Trichomes rusty-brown, long, simple, unicellular, unbranched, acutely pointed dense outgrowths from the epidermal cells, nearly straight or somewhat curly distally, occasionally subclavate, short or irregular ; rarely arising in fasciculate bundles, but never multicellular. The trichogenous epidermal cell is produced into a short, truncate proximal base, beyond which is the hair cell. The great mass of the gall comprises closely packed parenchyma cells. Fully mature gall measures about 20-25 mm in diameter. Occurrence abundant : nearly every flower being galled. Pupation probably in gall after a slight larval diapause.

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*Contribution No. 37 from the School of Entomology. Cecidological contribution No. 21.

Locality : Marudamalai Hills, Coimbatore, (South India) Coll. M. S. Mani & R. Krishnan, 14-vi-1952. Himayatsagar Farm, Hyderabad (Deccan. India), Coll. A. S. Rao.

Natural Order CAPPARIDACEAE

Crataeva religiosa Forst.

Gall No. 334 by *Aschistonyx crataevae* (Mani)* on flowers.

Plate VII

New gall. Regular discoid or subglobose, semi-solid, soft, fleshy, compound, indehiscent, yellowish-white, parenchyma gall formed by the complete composite irregular cortical outgrowths from the bases of stamens, of the entire staminal stalk, even also of the anthers partially or wholly, of the ovary, style

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* Mani, M. S. 1934. *Rec. Indian Mus.*, **36** :428; Rao, S. N. 1950. *ibidem*, **48**: 37.

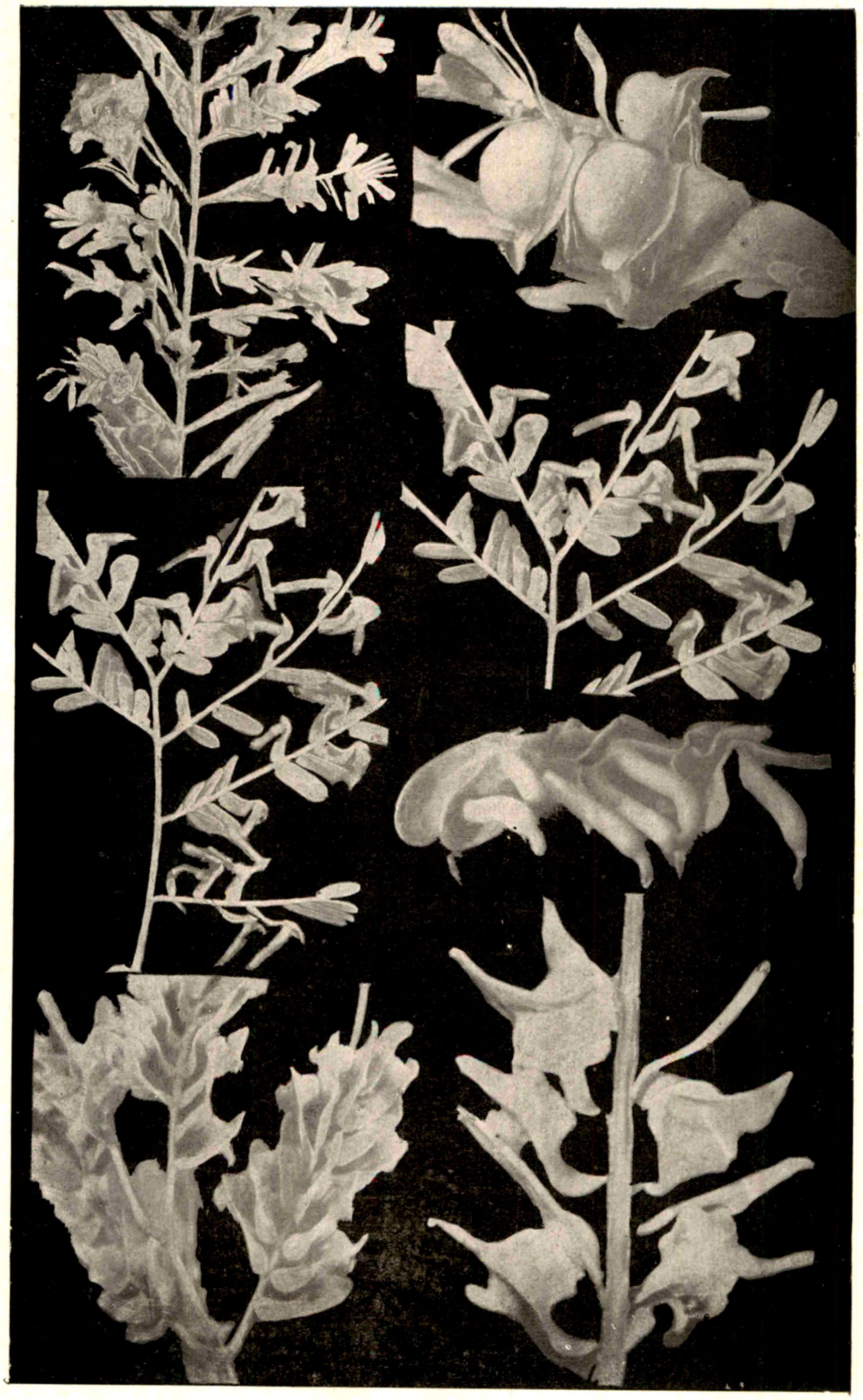
PLATE V.

M. S. Mani : Plant Galls

Top left : Leaf of *Acacia catechu* Willd., with Gall No. 209 caused by ***Lobopteromyia bivalviae*** (S. N. Rao) ; right : Three examples of the same gall more highly magnified.

Middle left right above : Leaf of *Acacia suma* Ham.-Buch, with Gall No. 453 caused by an unknown midge ; right below : part of a single pinna with same gall in serial growth, more highly magnified.

Bottom left : Part of leaf of *Acacia suma* Ham.-Buch. with serial gall No. 456 caused by *Lobopteromyia ramachandrani* Mani ; right : part of single pinna more highly magnified to show the characteristic series-formation of the gall.



M. S. Mani : Plant galls.

and of the fleshy swellings of the petals. Irregular narrow interspaces between the fleshy lobes of the gall contain over a dozen yellow-coloured larvae of the midge. Where the staminal bases alone are moderately swollen, the much enlarged anthers enclose some pollen, but usually when the gall is mature, the entire stamen is enormously swollen, so that the sterile anthers remain sessile. Where the gynophore is swollen, the ovary remains partly normal and may occasionally contain a few ovules. Although the gall is indehiscent, it decays rapidly after the escape of the midge larvae that crawl out to pupate in soil. The mature gall measures about 10-15 mm in diameter. Occurrence abundant in May and early June.

Locality : Agra, Coll. M. S. Mani, April-May 1951-53.

Maerua arenaria Hook. & Blume

Gall No. 173 by *Schizomyia maeruae* Felt (?)* on leaf.

Plate VII

New gall. Regular, solid, pod-shaped, laterally compressed, indehiscent, spongy, parenchymatous gall on leaf about 40 mm long and 15 mm thick, smooth and glabrous or with irregular surface, yellowish to greenish-yellow; formed by the fusion and enormous swelling of the basal portion of the leaf blade on either side of the midrib, with the leaf margin often remaining unaltered and extending along the whole length of the gall above as a pair of narrow leafy outgrowths, between which is a more or less deep, irregular sulcus containing numerous irregular flashy tubercles. The gall bears a superficial resemblance to a fleshy, irregular indehiscent legume, winged along one margin. The surface of the gall corresponds to the lower surface of the leaf. In a transverse section can be seen an outer parenchyma with chlorophyll and a central core of larger, white parenchyma. The larval galleries occur in the latter zone. In mature galls several circular exit holes open irregularly on the surface. Pupation in gall.

Locality Coimbatore, South India ; Coll. Prof. B. L. Gupta & Mr. R. Krishnan 25-31. xii. 1952.

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* Felt, E. P. 1926. *Mem. Dept. Agric. India* (ent. Ser.) **9** ; 243; Mani, M. S. 1934. *Rec. Indian Mus.*, **36** : 106

Natural Order STERCULIACAE

Melhania futteporensis Munro

Gall No. 338 by an unknown midge on leaf.

Plate VIII

New gall. Regular, solitary, free, discoid, hard, beutel-galls visible equally on both sides of the leaf blade and as many as 20 galls on a single leaf; brownish or reddish-brown, smooth, finely pubscent; ostiole hypophyllous, rarely epiphyllous, on a narrow short, cylindrical or subconical chimney-shaped fleshy prolongation; on the upper surface there is a small circular discolourised spot in the centre; semi-persistent, indehiscent, unilocular; the gall cavity large, depressed-oval, central and surrounded by a thick zone of closely packed proliferating cells, within the peripheral zone of larger parenchymatous cells. Size of full grown gall 4 mm diameter and 2 mm thick. Larva orange-red, single in each gall. Pupation in gall after prolonged larval diapause, in one case two extending to more than years.

Locality : Reserve Forest, Bund Bareta in Bharatpur State; Coll. M. S. Mani, 23 September, 1951.

Natural Order BURSERACEAE

Commiphora caudata Engl.

Gall No. 409 by *Eriophyes* sp. on inflorescence.

Plate VIII

New gall. Irregular, extensive, diffuse, superficial, solid, fleshy, tubercular, brownish-yellow, closely crowded emergences, simple or irregularly lobed or branched, involving the entire inflorescence, which consequently becomes greatly stunted, contorted and deformed; all the floral parts remain undeveloped and the flowers fail to open. Pedicels and inflorences axis somewhat swollen due to cortical hypertrophy.

Locality : Coimbatore, South India; Coll. M. S. Mani, 20, vi. 1952

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*Vide infra.

Gall No. 410 by *Eriophyes* sp. on leaves.

New gall. Similar to gall No. 409, but involving the tender leaflets.

Locality : Coimbatore, South India; Coll. M. S. Mani, 20. vi. 1952.

Natural Order LEGUMINOSAE

Acacia catechu Willd.

Gall No. 209 by *Lobopteromyia bivalviae* (Rao)* on leaflets.

Plate VI

Regular, globose, free, solitary or serially numerous, simple, hard, hollow, unilocular, dehiscent, persistent, bivalved galls formed of unequally enlarged swollen and cup-shaped bases of two adjacent leaflets on the same side of the pinna; the proximal valve smaller and terminal valve larger; the two valves fitting each other accurately by the broad brims to form a spherical pot and circular discoid lid; the apices of the leaflets thus affected remain normal; often the narrow margins of the leaflets also free. The colour of the galls varies from dark reddish-brown to violet. The surface smooth, and glabrous. Each gall is attached by a very short petiole or is subsessile. The smaller valve projects partly into the lumen of the gall like a circular cork-like plug. Size varies from 3-3.5 mm in diameter. Rarely three leaflets form a single gall. Larvae 1-2 in each gall. Occurrence extremely abundant, each leaf bearing on an average about 50 galls and nearly every leaf on a plant being galled.

This gall was first collected by me from the Reserve Forest, Walayar, south of Coimbatore in 1926, but no midges were reared.† In 1950 some specimens of the gall and one single example of a midge were received from Thana (Bombay) through the courtesy of the Forest Research Institute, Dehra Dun.

Locality : Walayar Reserve Forest, along railway line to the north of the Walayar Station; coll. M. S. Mani & R. Krishnan, July & December, 1952.

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*Rao, S. N. 1950. *Rec. Indian Mus.*, **48** (3-4): 35, fig, 4.

†Mani, M. S. 1935. *Rec. Indian* Mus., **37** (4) : 447-448, fig. 13a; *J. Roy. Asiatic Soc. Bengal* (Sci.) **14** (2): 139 (1948);

Acacia Suma Buch.-Ham.

Gall No. 453 by unknown midge on leaf.

Plate VI

New gall. Regular, simple, persistent, elongate, slender, cylindrical, solid, indehiscent, yellowish-green, reddish-brown or violet-coloured, smooth, glabrous, unilocular galls on leaves, consisting of a hollow cylinder formed as an epiphyllous local evagination from one leaflet, into which fits a solid, cylindrical, rod-shaped piston formed as a solid parenchymatous local epiphyllous outgrowth from the next leaflet above (apically) on the pinna. The solid piston fits close to the hollow cylinder but does not extend right down to its tip; a short narrow, somewhat curved apical hollow part of the outer cylinder forms the larval cavity (gall cavity) and contains a single larva of the gall midge. Each gall is thus formed from at least two leaflets. The cylinder is basally provided with a short, stout, fleshy, circular hypophyllous rim projecting conspicuously beneath and girdling the narrow solid piston. The site of the solid piston is indicated on the opposite side of the leaflet bearing it by a discolourised raised spot with a shallow central depression. The cylinder-piston galls arise in continuous interlocked series and succeed one another on the pinna; each leaft providing the cylinder for one gall basally and piston for another apically. Size varies from 9 mm to 10 mm in length and 1-1.5 mm in diameter. Each gall is nearly twice or more the length of the leaflet on which it develops.

Locality : Reserve Forest near Walayar Railway Station, south of Coimbatore, South India; Coll. R. Krishnan, July 1952; & M. S. Mani & R. Krishnan, 26 xii, 1952.

Gall No. 456 by *Lobopteromyia ramachandrani* Mani* on leaflets.

New gall. Regular, agglomerate, serial, persistent, barrel-shaped and obliquely arranged on either side of the pinna of leaf, each gall formed of a barrel-shaped, stout, proximal, hollow, thick-walled growth from the upper surface of one

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*Vide infra.

PLATE VI.

M. S. MANI : PLANT GALLS

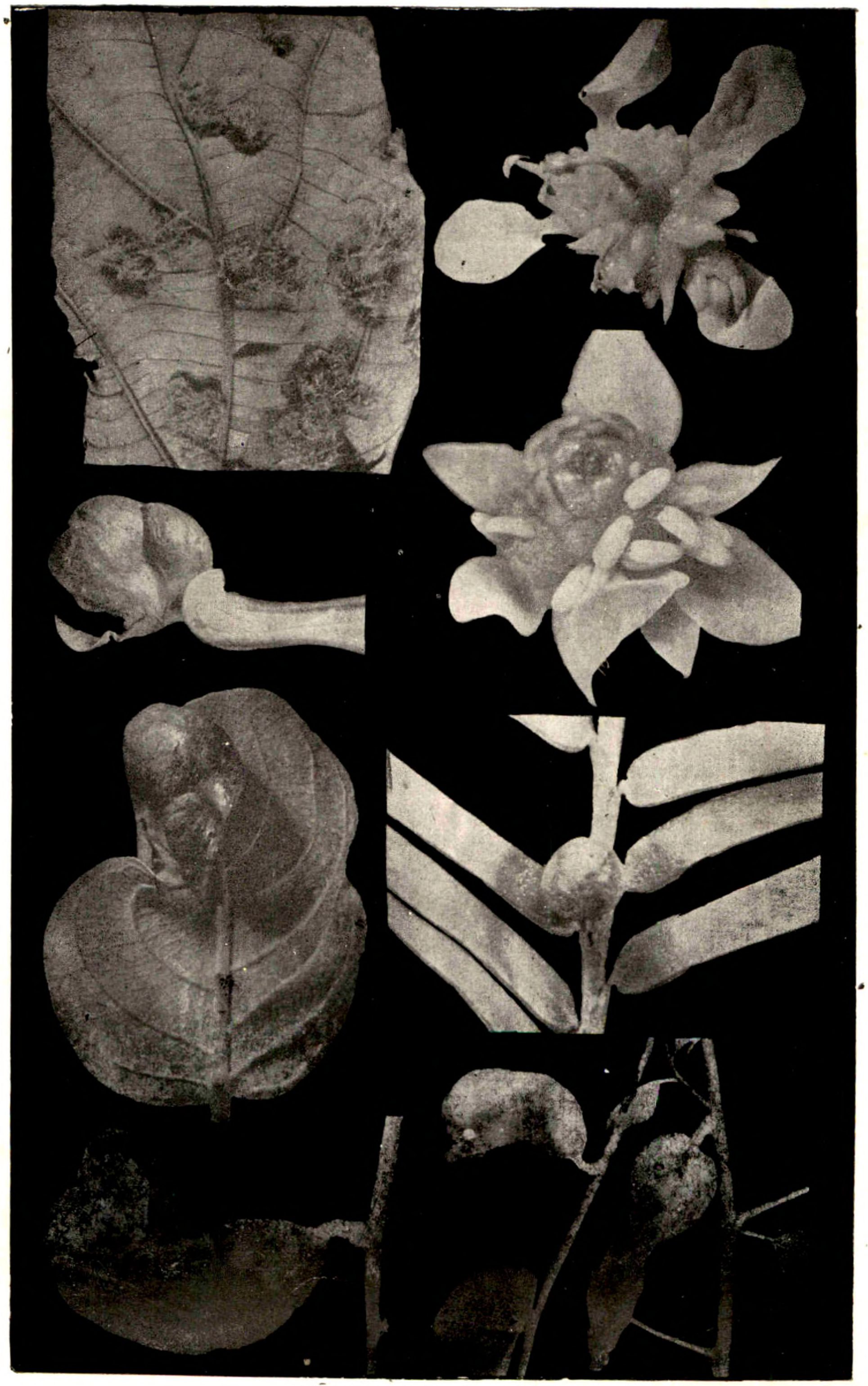
First (from the top) row left : Gall No. 414 on leaf of *Tectona grandis* Linn. caused by an unknown midge.

First and second rows right : Gall No. 334 on flowers of *Crataeva religiosa* Forst. caused by *Aschistonyx crataevae* (Mani).

Second and third rows left : Gall No. 327 on leaf of *Terminalia* sp. caused by an unknown thrips.

Third row right : Part of leaf of *Emblica officinalis* Gaertn., with Gall No. 472 caused by an unknown midge.

Bottom left and right : Gall No. 173 on leaf of *Maerua arenaria* Hook. & Blume, caused by *Schizomyia maeruae* Felt (?).



M. S. Mani : Plant galls

leaflet, into which fits a short, stout, stumpy-cylindrical, pestle-like plug formed from the swollen disc-like lower side of the next leaf above, which in its turn bears a hollow barrel for the next gall in the series. Each barrel of the gall is prolonged into a long, curved, fleshy process from the conical free end. Each gall is unilocular, hard, dehiscent, yellowish-brown, irregularly rugose and measures about 3.5 - 4 mm long and 2.5 mm thick The apices and margins of the leaflets bearing the gall free and normal. The plug reaches nearly to the bottom of the gall cavity which contains a single larva of the midge. Every leaflet of every leaf galled so as to form leaft curling in severe cases.

Locality : Reserve Forest near Walayar Railway Station, south of Coimbatore, South India ; Coll. R. Krishnan, July 1942 ; M. S. Mani & R. Krishnan, 26. xii. 1952.

Natural Order COMBRETACEAE

Anogeissus latifolia Wall.

Gall No. 320 by an unknown psyllid on leaf.

New gall. Regular, pyriform or globose, free, solitary, agglomerate, epiphyllous, fleshy, thick-walled yellowish-green or brown, glabrous beutelgalls, with minute hypophyllous ostiole on a small, subconical, fleshy prominence.

Locality : Jhabua, Central India ; Coll. R. D. Saksena, 19. vi. 1946.

Terminalia paniculata Roth.

Gall No. 466 by an unknown midge on buds and branches.

Plate VIII

New gall. Regular, cordate or pyriform, hard, woody, solid, indehiscent, solitary, aggregate or conglomerate irregular woody masses, with a solid dark brown callus-cell piston-like lid, slightly projecting from a circular ostiole on the summit of the gall and reaching nearly down to the bottom of a tight-fitting cylindrical gall-cavity ; a single larva of the gall midge lies beneath the lower end of the solid piston. When the gall is mature and old, the piston-like lid becomes rather loose and is pushed off easily, leaving a neat circular exit hole. Each solitary gall measures about 10 mm long and 7 mm thick basally. Ostiole about 2 mm in diameter and leads into a straight, long, narrow, cylindrical axial tunnel. When immature and newly forming, the surface of the gall is brown and smooth, but when old grey and covered by pealing bark. The largest conglomerate gall may measure about 35 mm in diameter and may be composed of over 50 separate galls. A gall frequently grows on the side of another gall.

Locality : Near Railway bridge to the north of Walayar Railway Station, south of Coimbatore ; Coll. R. Krishnan, July 1952 ; M. S. Mani & R. Krishnan 26. xii. 1952.

Terminalia sp.

Gall No. 327 by an unknown thrips on leaf.

Plate VII

New gall. Regular, hollow, hypophyllous, leathery, utricular, pyriform or subglobose, sessile, solitary, free or often irregularly agglomerate and large-lobed, yellowish-green or brown, rugose beutelgalls, with large irregular cavity. The gall is usually developed near the tip of the leaf blade.

Locality : New Forest, Dehra Dun; Coll. M. S. Mani & S. N. Rao, July, 1950.

Natural Order VACCINIACEAE

Vaccinium leschenaultii Wt.

Gall No. 354 by an unknown aphid on bud.

Plate VIII

New gall. Irregular, lobed, globose, hollow, utricular, leathery, thin-walled, dehiscent, brownish to reddish, glabrous swellings from the terminal buds and terminal leaves, measuring upto about 80-90 mm in diameter, with numerous irregularly bursting ostioles on the irreguler lobes. Gall cavity large, irregular, tortuous, covered by a fine powdery wax secreted by the numerous aphid nymphs.

Locality : Kodaikanal Hills, South India; Coll. T. N. Ananthakrishnan, 25. ix. 1951.

PLATE VII.

M. S. MANI : PLANT GALLS

Top left and right : Gall No. 260 on leaf of *Machilus gamblei* King, caused by ***Daphnephila hassi*** Kieff.

Middle row left above : Gall No. 465 on branches of *Terminalia paniculata* Roth., caused by an unknown midge.

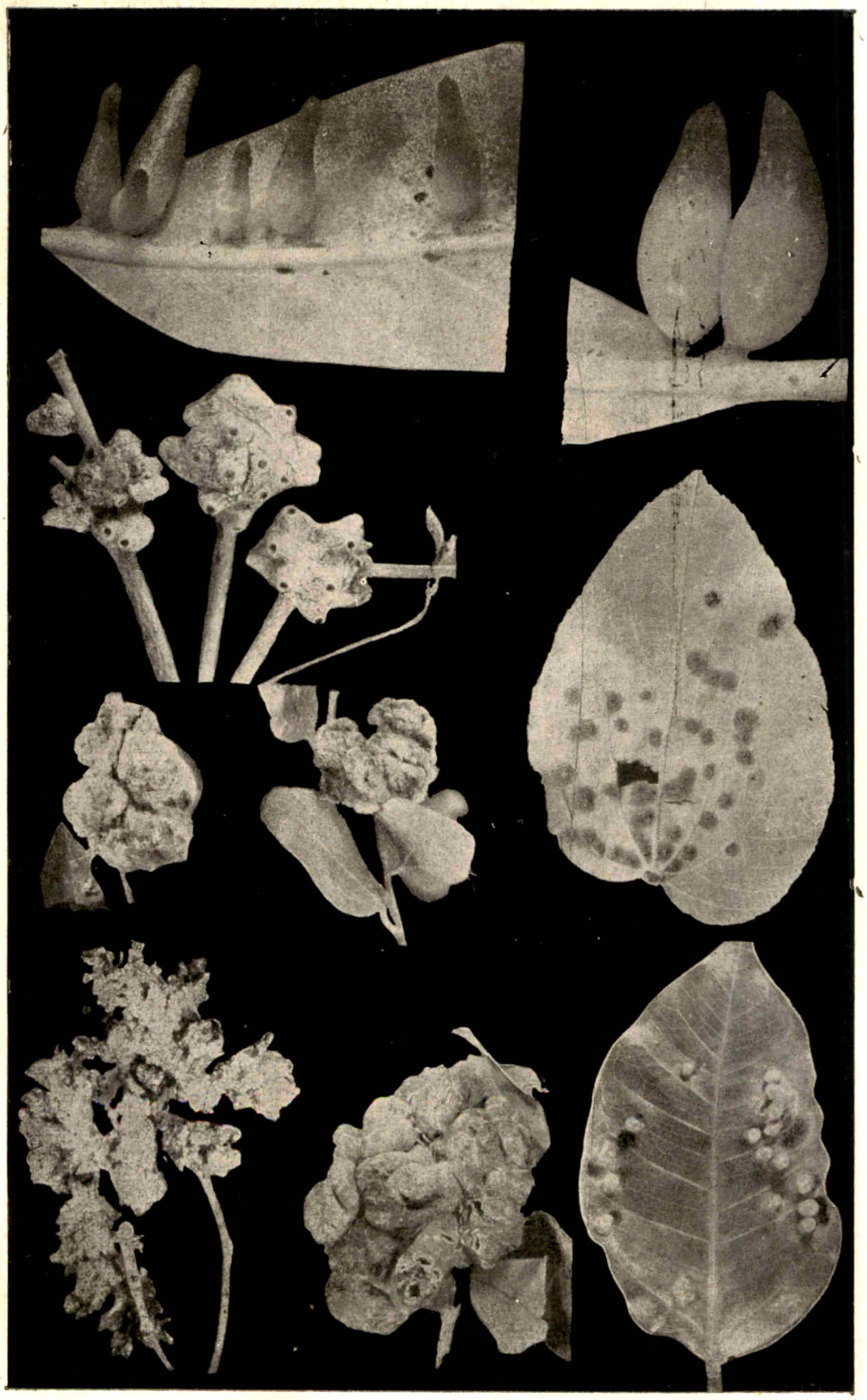
Middle left below : Gall No. 349 on flowers of *Cocculus hirsutus* Diels., caused by an unknown midge.

Middle row left : Leaf of *Melhania futteporensis* Munro, with Gall No. 338 caused by an unknown midge.

Bottom left : Gall No. 409 on inflorescence of *Commiphora caudata* Engl., caused by *Eriophyes* sp.

Bottom centre : Gall No. 354 on bud of *Vaccinium leschenaultii* Wt., caused by an unknown aphid.

Bottom right : Leaf of *Ficus infectoria* Roxb. with Gall No. 407 caused by *Trioza* up.



M. S. Mani : Plant galls

Natural Order SAPOTACEAE

Bassia latifolia Roxb.

Gall No. 321 by an unknown chalcid on leaf.

New gall. Regular, hypophyllous, simple, free local or subextensive, solid, oval or fusiform, indehiscent, persistent, often moniliform swellings of every vein of nearly every leaf; brown, smooth, glabrous, unilocular; over 200 galls on each leaf; about 4-5 mm long and 1-2 mm in diameter.

The gall maker belongs to the Tetrastichidae and the adults emerge in very large numbers in spring and early summer and the eggs are deposited on the newly forming leaves. The galls grow rather slowly and reach maturity next spring.

Locality : Hewett Park, Agra; Coll. M. S. Mani & S. N. Rao, March 1950.

Bassia longifolia Linn.

Gall No. 352 by an unknown midge on midrib.

New gall. Regular, simple, fusiform, solid, indehiscent persistent local swellings of the midrib, more conspicuous on the lower surface of leaf than on the upper, about 10 mm long and 3 mm thick; larval cavity irregular, longitudinal. The bark cracks longitudinally and exposes the cortical growth beneath.

Annamalai University Campus, Chidambaram, South India; Coll. M. S. Mani, 15. 1952.

Gall No. 353 by an unknown midge on leaf blade.

New gall. Regular, simple, free, solitary, solid, hard, indehiscent, discoid, greenish swellings of the leaf blade, equally visible on both sides of the blade, with small circular exit holes irregularly scattered on the surface. Size of the gall 3-5 mm in diameter. Surface rugulose.

Locality : Annamalai University Campus, Chidambaram; Coll. M. S. Mani, 15. i. 1952.

This gall is probably the same as No. 2540 recorded by Houard* from India.

Gall No. 362 by an unknown midge on branches.

New gall. Irregular, solid, indehiscent, local cortical outgrowths from the tender branches, which become exposed by the bursting of the bark due to stretching.

Locality : Annamalai University Campus, Chidambaram; Coll. M. S. Mani, 15. i. 1952.

Natural Order ASCLEPIADACEAE

Pergularia extensa N. E. Br.

Gall No. 462 by an unknown midge on flowers.

New gall. Regular, subglobose, solid, fleshy, solitary, simple, indehiscent, pubescent, pale green swellings of flowers, about 5 mm thick, with 2-3 larval cavities. Pupation in gall.

Locality : Marudamalai Hills near Coimbatore; Coll. R. Krishnan, 30-xii. 1952.

Natural Order BORAGINACEAE

Ehretia laevis Roxb.

Gall No. 318 by *Eriophyes* sp. on flowers.

New gall. Irregular, solid, fleshy, greenish swellings of the entire floral axis involving the calyx, corolla, stamens and pistil, their tips often enlarged and swollen thick leafy stumps; often the entire tip of the inflorescence becomes galled. Each gall is lobulated, and encloses irregular narrow passages. The erineal pubescence white when young and fresh, but rusty-brown when old, unicellular elongate, straight, acute. The calyx expands into an irregular unlobed fleshy cup-like base from which the other swollen floral parts project up; sometimes the tips of one or two sepals remain free and form a leathery, incomplete sheath for the gall. All the floral parts turn green and leafy, spongy outgrowths,

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*Houard, C. 1922-23. Les Zoocecidies des plantes d' Afrique, d' Asie et d' Oceanie, p. 710, No. 2540; *Marcellia*, **17**: 147 (1921).

enclosing numerous interspaces. The mites occur in enormous numbers both on the outer surface of the gall and in the crevices between the spongy mass. Predatory mites are common. Each of the modified floral parts bear irregular fleshy emergences, from which arise the trichomes. Size 20 mm in diameter and 10-15 mm thickness.

Locality : Garden, St. John's College, Agra; Coll. M. S. Mani 19. v-18. vi. 1945; 29. ii. 1952.

Gall No. 401 by *Eriophyes* sp. on leaf.

New gall. Irregular out-pocketings, with leaf blade crumpled, swollen and deformed to give rise to small pustule-like beutelgalls, filled with dense erineum. Usually isolated or often also extending to almost the entire leaf blade.

Locality : Garden, St. John's College, Agra; Coll. M. S. Mani 17. iv. 1952.

Natural Order SCROPHULARIACEAE

Striga orobanchoides Benth.

Gall No. 468 by an unknown weevil on stem.

New Gall. Diffuse, local fusiform, indehiscent, hollow swellings of tender branches, with a single larval tunnel; measuring about 8 mm long and 5 mm thick.

Locality : Himayatsagar Farm, Hyderabad (Deccan) ; Coll. A. S. Rao, 15, xii, 1952.

Natural Order VERBENACEAE

Tectona grandis Linn

Gall No. 414 by an unknown midge on leaf.

Plate VII

New gall. Regular, depressed, circular, discoid, hypophyllous beutelgalls, about 3-4 mm in diameter and 1 mm high, solitary, isolated, shortly pedicelled, covered by moderately dense, long, straight, simple, cottony-white pointed, villous trichomes unicellular, thin-walled, indehiscent. Ostiole minute, epiphyllous.

The galls are usually densely crowded on the leaf, often over 300 galls per leaf, giving it a cottony-woolly appearance. On the upper surface of the leaf the site of the gall is indicated by a small fleshy tubercle. Each gall is attached to a vein. A single larva in each gall.

Locality : Forest Office Trivandrum; Coll. K. J. Joseph, 2. vii. 1952; Walayar Reserve Forest near Walayar Railway Station, south of Coimbatore; Coll. R. Krishnan, July, 1952.

Natural Order LAURACEAE

Machilus gamblei King

Gall No. 260 by *Daphnephila hassi* Kieff.* on leaf.

Plate VIII

Regular, free, solitary, hypophyllous, fusiform, somewhat basally stout beutelgalls, solid, indehiscent, yellowish-green, glabrous, parenchymatous, moderately hard, shortly and narrowly pedicellate; apically with a short, stumpy, fleshy, subconical mucronate process; unilocular; the gall cavity axial, elongate, slender, cylindrical and extending from nearly the very base of the gall to its apex, with a single larva; very often crowded or in bunches but never conglomerate; each gall is inserted on the midrib or also one of the larger side veins; size about 12-18 mm long and 3-5 mm thick subbasally; occasionally epiphyllous.

Locality : New Forest, Dehra Dun; Coll. Chandy Kurian 8. ii. 1953.

This gall was originally described very briefly by kieffer (*loc. cit.*) from Kurseong.

Natural Order BUXACEAE

Sarcococca brevifolia Stapf

Gall No. 467 by *Eriophyes* sp. on leaf.

New gall. Irregular, epiphyllous, hemispherical, beutelgalls, with large ostiole below. Yellow-green, reticulate, glabrous.

KIEFFER, J. J. 1945. Etude sur le nouveaux Insectes et Phytoptides gallicoles du Bengale *n4S An.oc Sci. Bruxlles*, **29** (2) : 14-148, pl. ii, 1, 5, 6, 8, 27, 29.

Erineum inside the gall cavity simple, brownish when young and rusty when old. Size about 5 mm. in diameter. Often agglomerate. Usually about 50-60 galls per leaf. Occasionally a gall may be hypophyllous.

Locality : Doddabetta 8000 ft. Nilgiris South India ; Coll. M. S. Mani, 28. xii. 1952.

Natural Order EURHORBIACEAE

Emblica officinalis Gaertn.

Gall No. 472 by an unknown midge on leaf.

Plate VII

New gall. Regular, globose, fleshy, solid, unilocular soft, glabrous, pale green or yellow-green galls in the axils of the leaf, about 3 mm in diameter.

Locality : Walayar Forest, South of Coimbatore ; Coll. R. Krishnan, 26. xii. 1952.

Natural Order MORACEAE

Ficus bengalensis Linn.

Gall No. 469 by an unknown midge on leaf.

New gall. Regular, minute, lenticular, yellowish, solid, pustuloid, nearly circular, indehiscent, unilocular, glabrous swellings of the leaf blade, about 2.5 mm in diameter, visible equally on both sides of the blade.

Locality : Coimbatore ; Coll. R. Krishnan, 30. xii. 1952.

Ficus infectoria Roxb.

Gall No. 407 by *Trioza* sp. on leaf.

Plate VIII

New gall. Regular, simple, occasionally agglomerate, free and isolated or frequently crowded, epiphyllous, dehiscent, unilocular, thick fleshy-walled, glabrous, yellow or pale white globose beutelgalls, with hypophyllous ostiole ; size of each gall ranging from 3 to 6 mm in diameter. Single nymph of the psyllid in each gall. On an average up to about a dozen galls per leaf.

Locality: roadside trees near Marudamalai Hills, near Coimbatore, South India; Coll. M. S. Mani, 13-vi-1952.

Ficus religiosa Linn.

Gall No. 323 by *Trioza* sp. on leaf.

New gall. Regular, free, subglobose or hemispherical epiphyllous, hollow, thin-walled, indehiscent, unilocular, persistent beutelgalls, with wide-open hypophyllous ostiole, green or yellowish-green, glabrous; with a single nymph of the psyllid in the bottom of the pit-like gall cavity; size above 2 mm in diameter.

Locality: Garden, St. John's College, Agra; Coll. S. N. Rao, 1950.

B. DESCRIPTION OF MIDGES

Family ITONIDIDAE

Subfamily *ITONIDIDINAE*

Tribe BIFILINI

Lobopteromyia bivalviae (Rao)

1950. *Cincticornia bivalviae*, S. N. RAO, *Rec Indian Mus.*, **48** (3-4): 35-37, fig. 3, 4, (New synonym).

Rao described this species from a single female specimen reared from gall No. 209 on leaf of *Acacia catechu* Willd. (Plate VI) collected by the Forest Ranger, Shahpur (Thana Dt.), Bombay, but placed it erroneously in the genus *Cincticornia* of the Asphondylini. Recent rearings by Mr. S. Ramachandran from the same gall collected by Mr. R. Krishnan from Walayar Forest, near Coimbatore, yielded several males and females and established the Bifiline affinities of the species. Opportunity was also taken to re-examine the type specimen of Rao. Rao's published description and the figures of the type differ in several essential characters from the actual specimen. I have therefore redescribed the female in addition to including a full description of the male.

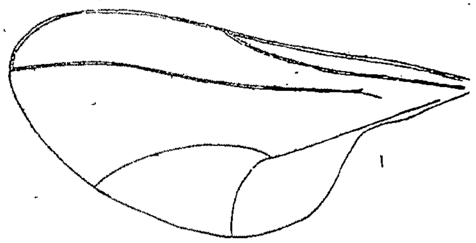
Female.—Length 1.5—1.75 mm. Reddish-brown. Eyes confluent above. Antennae short, light brown, about half the length of body, with 14 segments; antennal flagellar segments short, subsessile, gradually becoming shorter and more slender apically; scape wider apically, width at apex about one and a half times the length; pedicel subcylindrical, about one and a half times as long as thick; first flagellar segment cylindrical, about two-thirds the combined length of scape and pedicel; second flagellar segment fused with the first, three times as long as thick, with a very short stem· second segment about two-thirds the length of the first; third segment slightly thicker basally than apically, about one and a half times as long as thick; fifth segment shorter than third, subglobose, about one and a half times the thickness ; sixth and seventh segments equal to the fifth ; ninth segment nearly globose; tenth segment equal to the ninth ; terminal two segments subequal. Palpi quadriarticulate; first segment a little less than one and a half times as long as thick; second, third and fourth segments equal. Abdomen reddish-brown. Wing as in figure 2. Metatarsus equal to the fifth tarsal segment, a little less than half the second tarsal segment, the latter somewhat shorter than the fourth tarsal segment. Claw simple, equal to empodium.

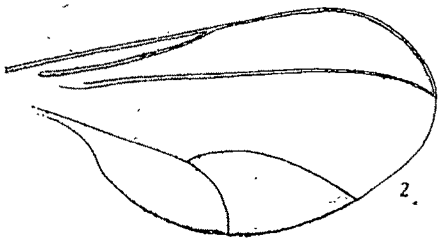
Male.—Length 1.2 mm. Reddish-brown in preserved material. Palpus quadriarticulate, long, slender, sparsely setose: first palpal segment short, slender, cylindrical; second, third and fourth segments subequal, somewhat stouter than the first and about two and a half times the length of the first. Antennae with 14 segments; flagellar segments binodose, with the stems short; third and fourth antennal segments fused together, enlargements oval; antennal segments fifth to tenth nearly equal to fourth in length; fifth segment with basal stem about one-tenth the length of the segment and a little over half its own diameter, stout; basal enlargement globose; apical stem a little more than twice the length of basal stem, but more slender, length nearly equal to diameter. Apical stem of sixth to ninth segments somewhat more slender than that of fifth segment. Basal stem of tenth segment somewhat more slender than that of fifth segment; apical stem slightly longer and more slender. Twelfth antennal segment about five-sixths the length of the fifth segment; apical stem with a length about twice the diameter. Thirteenth segment with apical stem twice as long as thick. Fourteenth segment equal to the twelfth, apically with a prolongation about half the apical enlargement. Wing as in fig. 2, nearly two and a half times as long as wide. Legs short ; femur a little shorter than tibiae ; tibia nearly twice the length of second tarsal segment ; terminal tarsal segment slightly shorter than the penultimate segment and about half the third segment, which latter is a little more than half the second ; first tarsal segment about equal to the terminal segment ; claw simple on all legs, moderately stout, strongly curved near tip ; empodium nearly equal to claw. Dorsal plate of male genitalia deeply bilobed, the lobes large, broadly oval, broadly rounded apically, emarginate. Ventral plate more deeply bilobed than the dorsal plate, the lobes much narrower than those of the dorsal plate, not heavily sclerotized, elongate-triangular, rounded apically and slightly shorter than dorsal plate. Terminal clasp segment moderately stout, more than three-fourths the length of basal clasp segment but not quite reaching the base of the genitalia when folded back, apically rounded and with one short acute, curved tooth.

Allotype 1 male dissected on slide, reared from gall No. 209 by Mr. S. Ramachandran, Coimbatore from material collected at Walayar Forest. In the collections of the Zoological Survey of India, Calcutta.

Lobopteromyia ramachandrani, sp. nov.

Male.—Length 0.75 mm. including genitalia. Brown in preserved state. Palpus quadriarticulate, short ; basal segment short, slender, a little less than half the length of the second segment; third palpal segment with a length a little over twice its own thickness ; fourth segment about one and one-fourth the length of the third. Antennae nearly as long as the body; with circumfila equal, not much longer than stems ; which are in each case longer the enlargements; segments 14; scape short, wide, cup-shaped; pedicel globose; first and second flagellar segments (third and fourth antennal) fused together; third flagellar segment with basal stem about one-eighth the length of the segment and one-third the diameter of the basal enlargement; basal enlargement of third segment with a diameter about three-fourths that of pedicel ; fourth antennal segment somewhat shorter than third, with relatively short stems ; fifth antennal segment nearly equal to third, with basal stem about half the diameter of the basal enlargement, short, thicker than long, its thickness a little less than twice its own length; apical enlargement and stem like the basal enlargement and stem; sixth antennal segment slightly shorter than fifth, apical stem slightly more slender than basal stem; seventh antennal segment a little longer than sixth segment, with apical stem nearly one and a half times the length of basal stem and relatively slender, longer than thick; basal stem distinctly thicker than long; basal and apical enlargements with a diameter about twice





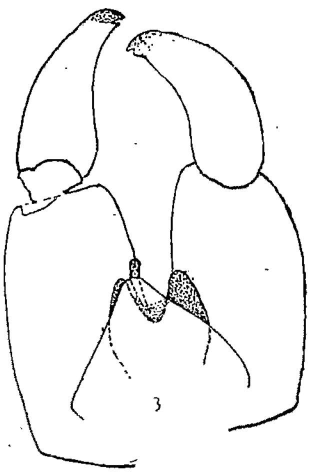


FIG. 1. *Lobopteromyia ramachandrani*, sp. nov., male, wing. FIG. 2. *Lobopteromya bivalviae* (S. N. Rao), male, wing. FIG. 3. *Lobopteromyia ramachandrani*, sp. nov., male genitalia.

the length of apical stem and length about three-fourths their own diameters; eighth segment equal to sixth but with apical stem one and a half times the length of the basal stem and equal to its own diameter; enlargements somewhat smaller than those of the preceding segment; ninth segment equal to eighth, tenth segment equal to ninth but with apical stem distinctly longer than thick; its basal stem distinctly stouter than long; eleventh and twelfth segments equal to tenth but with enlargement smaller; thirteenth segment equal to the preceding segment but with the apical stem somewhat shorter than that of the tenth segment; fourteenth segment distinctly shorter than the preceding segments, basal enlargement subglobose and apical enlargement subpyriform with a short hemispherical terminal process about one-fourth the diameter of the enlargement. Wing short, broad, with posterior area broadly rounded as in figure; vein R_5 reaching margin just beyond apex; fifth vein forked; no cross-vein. Legs short, fore tibia about eight times the length of the first tarsal segment; second tarsal segment nearly three times the first; third tarsal segment about half the second; fourth and fifth tarsal segments equal to the first tarsal segment; claw slender, simple on all legs, evenly curved; empodium equal to claw. Dorsal plate of genitalia large, obtusely triangular, wide basally, not bilobed; ventral plate nearly equal to dorsal plate, broadly bilobed apically, the lobes wide, short and triangular; style nearly equal to dorsal plate; basal clasp segment stout, densely setose; terminal clasp segment moderately stout, slightly curved, somewhat longer than three-fourths the basal clasp segment, apically with one stout subacute tooth.

Holotype 1 male on slide in the collections of the Zoological Survey of India, Calcutta. Reared from gall No. 456 on leaflets of *Acacia suma* (Plate VI) by Mr S. Ramachandran, from material collected by Mr. R. Krishnan at Walayar, 17. xii. 1952.

This species differs from *Lobopteromyia bivalviae* (Rao) chiefly in the dorsal plate of the male genitalia being obtusely triangular, ventral plate equal to the dorsal plate, broadly bilobed apically, the lobes broad, short, triangular; basal clasp segment densely setose and the style being equal to the drosal plate. These two species are easily separated from *Lodopteromyia prosopidis* Mani,* the only other species from India, by several characters. *L. prosopidis* causes gall No. 212 leaf of *Prosopis juliflora* and *P. spicigera.*

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*MANI, M. S. 1938. *Rec. Indian Mus.*, **40.** (4) : 334.

CONTRIBUTIONS TO OUR KNOWLEDGE OF FIG INSECTS (CHALCIDOIDEA: PARASITIC HYMENOPTERA) FROM INDIA.*

IV. Descriptions of Three New and Records of Four Known Species of Agaonini.†

By K. J. Joseph M. Sc., *Senior Research Scholar, Government of India, Ministry of Education, School of Entomology, St. John's College, Agra.*

The type specimens of the new forms described here are deposited in the collections of the School of Entomology for the time being.

I wish to acknowledge my great debt of gratitude to Prof. M. S. Mani for facilities for work, constructive criticism and for confirmation of my identifications.

Blastophaga constabularis, sp. nov.

Female.—Length 1.08 mm. Viewed from above ferrugino-testaceous; legs pale brown except for the whitish-yellow tarsi; eyes pale pinkish-red; antennae smoky-brown; ovipositor melleous, valves smoky-brown; wings hyaline with yellowish-brown pubescence, nervures amber.

Head (Fig. I. 1) wider between the external margins of the eyes than long; epistomal margin with a pair of lateral convex lobes and a median rounded projection bearing two pairs of seate; lateral margin of head forwards of eyes four-fifths the longitudinal diameter of the eye; posterior margin of head behind the eyes rounded off; eyes large; ocelli large, three in an obtuse triangle; dorsally the head bears a few small setae. Antenna (Fig. I, 2) with eleven segments; length of scape one and three-fourths its maximum width

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* Contribution No. 35 from the School of Entomology, published with the permission of the Professor of Zoology and Entomology.

† Part III, of this series was published in *Agra Univ. J. Res.* (*Sc.*) 2 (1): 53-82, Jan. 1953.

with a distinct angular projection laterally a little beyond basal half, with setae as in figure; segment two about one and a half times as long as thick, its proximal portion a little projecting over the scape, with setae as in figure; third segment partially divided into two parts, of which the distal bractiform part projects beyond the distal extremity of the fourth segment; fourth segment small, a little longer than thick; length of fifth one and a half times its thickness; sixth as long as fifth but a little less thick; seventh a little less than twice its own thickness; eighth one and one-third as long as thick; ninth and tenth segments thicker than long; ninth a little larger than tenth; eleventh segment one and a half times the ninth, with a thickness little more than half its own length; segments five to seven with whorls of long sensoria projecting a little beyond the distal margins of the segments and with setae; segments eight to eleven with setae and whorls of many large sensoria projecting well beyond the distal margins of the segments as in figure.

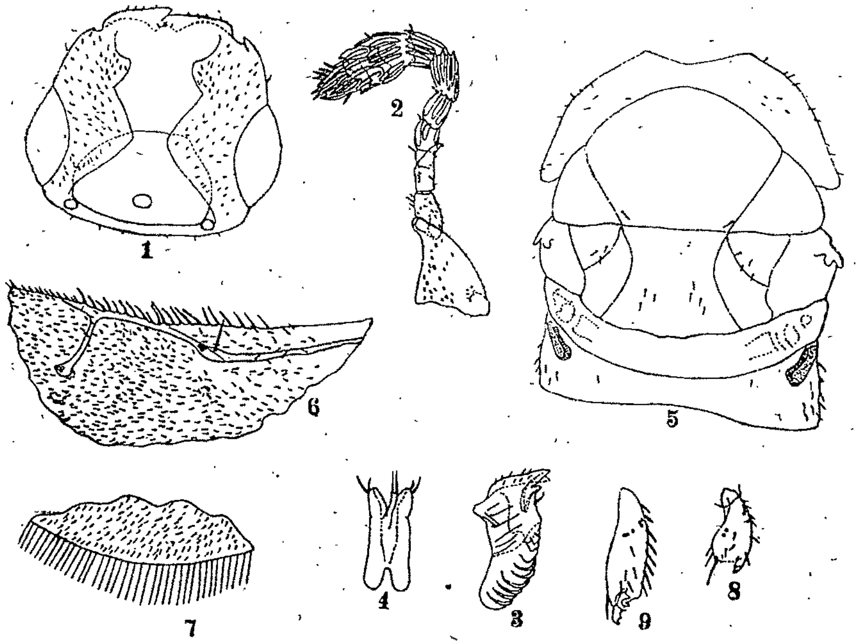

FIG. I.—*Blastophaga constabulars*, sp. nov. Female: 1, head; 2, antenna; 3, mandible; 4, maxillae and labium; 5, thorax; 6, portion of fore wing showing the wing veins; 7, portion of the posterior margin of the fore wing to show the marginal fringes; 8, fore tibia, outer aspect; 9, hind tibia, outer aspect.

Mandible (Fig. I, 3) large, as long as wide, furnished with many setae as in figure, bidentate, apical tooth large; appendage clearly longer than the mandible, with ten transverse laminar elevations*. Maxilla (Fig. I, 4) with two long setae subdistally. Labium (Fig. I, 4) with two long setae distally.

Thorax (Fig. I, 5). Pronotum furnished with numerous hairs. Mesonotum with the scutum provided with two long hairs laterally and subposteriorly; scapulae with a few short hairs laterally; axillae with about four long hairs near their inner margin; scutellum with about seven hairs in its posterior half; scapula as long as wide; scutum about one and one-third as broad as long; scutellum a little wider than long; axilla about as long as wide; parascutella twice as long as wide. Metanotum a narrow transverse area. Propodeum about six and a half times as wide as its median length, with numerous hairs laterally. Fore wing (Fig. I, 6) a little over twice as long as its maximum width; costal cell with pubescence in its distal half; submarginal vein a little over four times as long as the marginal and with a cluster of three sensillae as in figure; marginal vein about as long as the stigmal; stigmal vein subclaviform with an angular prolongation towards the distal margin of the wing, bearing two large and two small sensillae as in figure; postmarginal reduced, short and distinctly less than half the stigmal; alar cuticle with small yellowish-brown pubescence; marginal fringe (Fig. I, 7) long. Hind wing five times as long as wide, with small yellowish-brown pubescence; marginal fringe long; with three frenal hooks. Fore leg with coxa a little over twice as long as thick, with many setae; trochanter indistinct; femur long, two and two-thirds as long as its maximum thickness, with many setae; tibia (Fig. I, 8) two and one-third as long as thick, its dorsal margin with three dentate processes, the ventral margin with a single tooth-like process, and with long setae and a single long spur disposed as in figure; tarsi five-segmented, armed with long and stout setae, metatarsus equal in length to the two following segments combined; pretarsus with a pair of falciform claws and the large empodium

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*GRANDI, G. *Boll. Lab. Ent. Bologna,* 1: 75-80, figs. III-IV, 1928.

Mid leg long and slender; coxa thicker than long; trochanter distinct, longer than thick; femur about five times as long as its maximum thickness, a little recurved, with a faintly chitinised basal area, its dorsal margin faintly concave, ventral margin convex, with numerous long setae; tibia longer than femur, about eight times as long as its maximum thickness, subclaviform, its proximal half less chitinised than the distal half, with numerous long setae and a single long spur; tarsi about as long as the tibia, five-segmented, armed with long and stout setae, metatarsus a little shorter than the two following segments combined; pretarsus with a pair of small claws and the empodium. Hind leg with coxa twice as long as thick; trochanter longer than thick, with a few setae and sensillae; femur large, twice as long as thick, its external margin distinctly convex, with numerous long setae; tibia (Fig. I, 9) shorter than the femur, a little less than thrice as long as thick, with about seven sensillae in its basal half, with long setae and a complex tridentate process distally on the external face, its inner face with a long compressed, recurved and bifurcating spine; tarsi long, five-segmented, armed with numerous setae, metatarsus about one and one-third as long as the two following segments combined; pretarsus with a pair of falciform claws and the empodium.

Abdomen longer than wide; seventh urotergite with a pair of spiracles with large subovoid peritremes. Ovipositor one and one-fourth as long as the abdomen.

Holotype 1 female dissected on slides Nos. 14-6/1, 14-6/2, 14-6/3. Paratypes 24 females in spirit.

Geographical distribution. Collected by K. J. Joseph from figs of *Ficus infectoria* Roxb. from P. A. C. Grounds, Agra, 26th September, 1950.

Blastophaga arnottiana, sp. nov.

Female.—Length 1.2 mm. General body colour brownish-yellow, with darker hues in various parts. Legs and basal segments of antennae melleous, rest of antenna yellowish-brown; eyes pinkish-brown; ovipositor melleous, valves brownish.

Head (Fig. II, 10) a little longer than broad between the external margins of the eyes; lateral margin forwards of eyes a little convex anteriorly and longer than the longitudinal diameter of the eye; epistomal margin with a feeble median angulose projection and two submedian projections; posterior angles of head behind the eyes rounded, posterior margin of head very feebly concave in the middle; the median posterior chitinised area of the frons bisects the anterior ocellus; the sublateral chitinised area of the dorsum of head with minute setae. Eyes moderately large; ocelli three, almost in a straight line. Antenna (Fig. II, 11). Length of scape a little more than one and a half times its maximum thickness; the second segment twice as long as thick, with many backwardly directed spines; third segment subconical, recurved towards apex, ending in a laminate process; fourth longer than thick, narrow basally; fifth more than one and a half times as long as its own maximum thickness; sixth a little longer and thicker than the fifth; fifth and sixth with a few large elongate sensoria which occupy almost their whole length and project slightly over its distal extremity; seventh almost as long as sixth and about half as thick as long, some of the large elongate sensoria with which it is provided well projecting distally; eighth

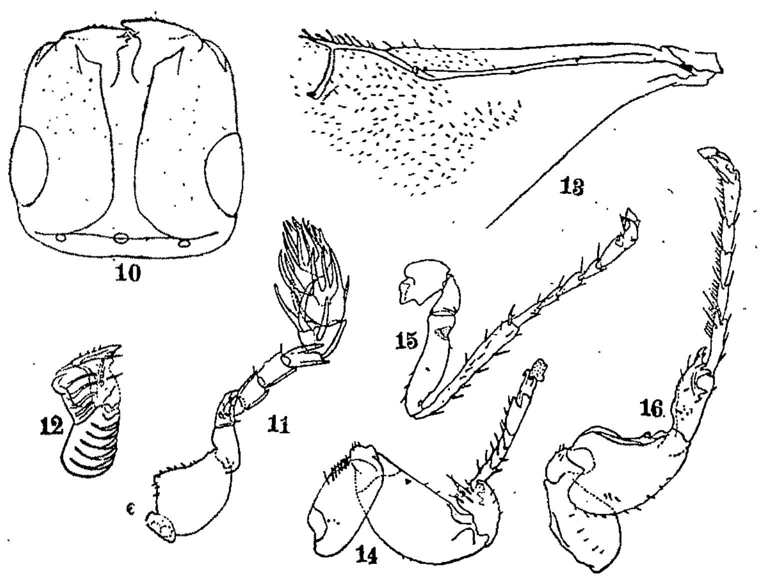

Fig. II.—*Blastophaga arnottiana*, sp. nov. Female: 10, head; 11, antenna; 12, mandible 13, portion of fore wing; 14, fore leg; 15, mid leg; 16, hind leg.

segment longer than and about twice as thick as the seventh, subtriangular, and provided with large elongate sensoria, some of which occupy its whole length and project slightly over its apex, others very long, rising from a large base at the distal margin of the segment and project to a distance equal to one to one and a half times the length of the segment; ninth and tenth segments similar to eighth though the ninth is a little shorter than both the eighth and the tenth and with similar sensoria; eleventh subfusiform, about twice as long as thick and provided with many long and projecting sensoria. Mandible (Fig. II, 12) large and strong, bidentate with large and acute apical tooth and short and blunt subapical tooth, a little wider than long; appendage about twice as long as wide, one and a half times as long as the mandible, with seven transverse ridges, the first and second (from the base) somewhat dentiform, with setae as in figure.

Thorax. Pronotum subtrap.zoidal, with a few small scattered hairs. Mesonotum with scutum provided with two long hairs laterally subposteriorly, wider than its maximum length; scapulae with about five short hairs laterally, as long as wide; axillae about one and a half times as long as wide with five to six hairs near its inner margin; scutellum wider than long, with four hairs situated at about equal distances from each other along its submedian latitudinal line; parascutellum longer than wide, bare. Metanotum a narrow transverse area with a few hairs. Fore wing (Fig. II, 13) a little less than twice as long as broad and rounded off at the distal extremity; length of submarginal vein a little more than four times the marginal; marginal a little less than twice the postmarginal; stigmal twice as long as the postmarginal, slightly tilted towards the distal extremity of the wing, dilated distally and with a beak-like prolongation bearing a set of three small rounded sensillae; costal cell a little over nine times as long as its maximum width, with many small hairs in its distal half; alar cuticle with small hairs; marginal fringe fairly long. Hind wing less than half as long as the fore wing and about four and one-third as long as broad; alar cuticle with very minute pubescence, with three frenal hooks; marginal fringe long. Fore leg (Fig. II, 14) with coxa about two and one-third as long as thick with setae as in figure; trochanter subtriangular, as long as thick; femur large, a little less than twice as long as thick with the ventral margin nearly substraight and the dorsal margin strongly arched; tibia a little less than half the femur, one and a half times as long as thick, narrow basally, widening towards apex and provided with a tridentate process on its outer surface and with long setae and a single long spur on its inner surface; tarsi about one and three-fourths the tibia, five-segmented, armed with setae, metatarsus a trifle longer than half the length of the tibia, second and third segments equal to the metatarsus, fifth longer than it; pretarsus with a pair of small claws and the large empodium. Mid leg (Fig. II, 15) with coxa one and one-fourth as long as thick; trochanter distinct, longer than thick, two-thirds the length of the coxa, one-third the length of the femur, with an incomplete division into two parts; length of femur three and three-fourths its thickness, its dorsal and ventral margins as in figure, with a distinct feebly chitinised area basally; tibia longer than the femur, eight times as long as thick, with many long setae and a spur of length about one-seventh the tibia; tarsi a little shorter than the tibia, five-segmented, armed with setae, second and third segments about equal to each other and a little shorter than the metatarsus, fourth shortest of all, fifth equal to the metatarsus; pretarsus with a pair of claws and the empodium. Hind leg (Fig. II, 16) with coxa a little more than one and a half times as long as thick and distinctly shorter than the femur, with a few setae as in figure; trochanter not very distinct; femur a little over one and a half times as long as thick, its dorsal margin convex and broadly arched, the ventral margin prominently convex at base and concave further on, with a distinct marginal dentate process, setae as in figure; tibia two-thirds the femur, a little less than two and a half times as long as thick, with a conspicuous tridentate armature situated at the distal extremity of its outer face and with a sublaminate and bifid apical spur, setae as in figure. "The tibia and the femur show a very interesting reciprocating mechanical arrangement. Towards the distal extremity of the ventral margin of the femur there is an angular projection strengthened by a chitinous thickening, which is prolonged proximally, thinning out beyond the middle of the femur and running in a submarginal direction. This projection is followed by an abrupt concavity of the margin and then by a rounded process. The tibia in the proximal half of its ventral margin has a rounded projection limited proximally and distally by two slight convexities."* Tarsi twice as long as the tibia, five-segmented, armed with setae and with a fringe of hairs on the ventral margin; length of metatarsus equal to about three-fourths the tibia and of the free ventral margins of the second, third and fourth segments taken together; fourth segment shortest of all, fifth a trifle longer than second: pretarsus with a pair of claws and the large empodium. Propodeum a little wider than the pronotum and a little less than three and a half times as wide as long, with long hairs laterally; propodeal tracheal spiracles linear, situated antero-laterally.

Abdomen one and three-fourths as long as high; eighth urotergite with a pair of spiracles with small subovoid peritremes; cercoides of the ninth urotergite with four bristles which are longer than the appendage, one of them being two and a half times as long; projecting portion of terebra one and a half times as long as the abdomen.

Male.—Length 1·2mm.* General colour melleous, with darker colourations in different regions; abdominal tergites smoky-brown; eyes blackish-brown.

Head (Fig. III, 17) a little longer than its maximum width; anterior and posterior angles of head rounded off; lateral margins of head largely convex; frons with an anterior inflection developing a deep concavity, and with a median cleft as in figure; epistomal margin weakly concave; posterior margin of head strongly convex and as in figure; dorsum of head with many small setae, those situated anteriorly being more robust and longer than those posteriorly; eyes small, situated well behind the anterior angles of the head. Antenna (Fig.

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* Grandi, G. *Bull. ent. Research,* **13:** 296-297, fig. I, 1923.

* Grandi, G. *Bull. ent. Research,* **13:** 296-297, fig. I, 1923.

III, 18) with five segments besides a radicle; length of scape twice its maximum thickness, with a few small setae; second segment twice as long as its maximum thickness, definitely longer than half the length of the scape; third thicker than long, with a whorl of setae; fourth twice as thick as long, transverse; fifth very large, slightly shorter than scape and about equal to it in thickness, provided at the distal end with a whorl of sensoria and a few short sensory setae. Mandible (Fig. III, 19) about one and one-third as long as wide, bidentate; teeth and setae as in figure.

Thorax. (Fig. III, 20). Pronotum wider than long, its anterior angles rounded off, anterior margin substraight, lateral margins faintly diverging backwards. Mesonotum transverse, about two and one-fourth as wide as its median length. Metanotum and propodeum fused together into one piece, its lateral margins converging backwards; posterior angles rounded off; propodeal teacheal spiracles with subreniform peritremes situated as in figure. Fore leg (Fig. III, 21) with

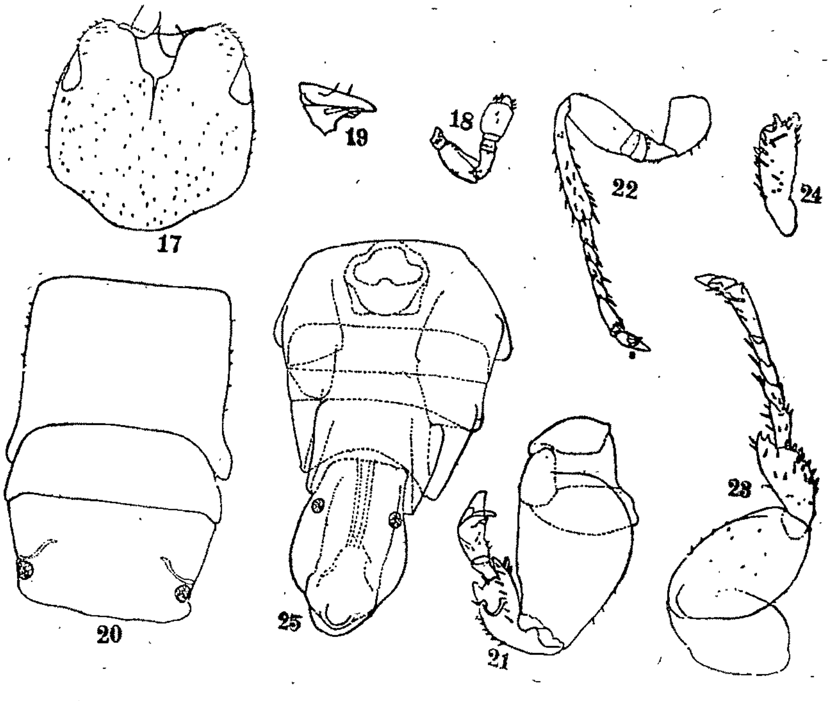

FIG. III.—*Blastophaga arnottiana*, sp. nov. Male: 17, head; 18, antenna; 19, mandible; 20, thorax; 21, fore leg; 22, mid leg; 23, hind leg; 24, hind tibia, outer aspect; 25, abdomen.

coxa about as thick as long; trochanter indistinct; femur large, a little more than one and a half times as long as thick; tibia a little over twice as long as thick, recurved as in figure, about half as long as the femur, its external aspect with a semicircular chitinous thickening limiting a distal concavity, with many setae and dentate processes as in figure; tarsi two-segmented, metatarsus a little longer than half the second segment, narrow basally, broadening distalwards, second segment large and subcompressed with a few setae; pretarsus with a pair of large curved claws and an enlarged empodium. Mid leg (Fig. III, 22) with coxa one and a half times as long as thick; trochanter distinct, subcompressed, one and a half times as long as its maximum distal thickness, narrow towards base and provided with a few setae and some rounded sensillae; femur subcompressed, a little less than thrice as long as its maximum thickness, with a faintly chitinised subtransparent area proximally, its ventral margin more strongly convex than the dorsal margin, with a few setae; tibia subclaviform, a little recurved, five times as long as thick, one and one-fifth the femur, furnished with many setae and rounded sensillae subproximally; tarsi five-segmented, a little longer than the tibia, armed with setae, the metatarsus a trifle longer than the following three segments taken separately, fifth segment longest of all; pretarsus with a pair of claws and the large empodium. Hind leg (Fig. III, 23) with coxa one and a half times as long as thick, with a few small setae; trochanter indistinct; femur large and compressed, a little less than one and a half times as long as its maximum thickness, its dorsal margin more strongly convex than the ventral margin, with many setae and numerous sensillae. Tibia subcompressed, large, shorter than the femur, thrice as long as thick, strongly narrowed at base, widening towards apex, slightly recurved, with a complex tridentate process at its extreme distal end on the external face (Fig. III, 24), and with a large laminar spine shaped somewhat like a claw, with recurved and forked apex. The tibia is in addition, provided with many robust setae, a few sensillae subproximally and a few stout odontoid spines on its outer margin. Tarsi five-segmented, longer than the femur, armed with long and stout setae; metatarsus long, widest at apex, second, third and fourth segments decreasing gradually in length, fifth segment longest of all; pretarsus with a pair of curved claws and the large empodium.

Abdomen (Fig. III, 25) two and one-third as long as wide, nine-segmented and as in figure; tracheal spiracles of the eighth segment with subovoid peritremes.

Holotype. 1 female dissected on slides Nos. 4-1/1, 4-1/2, 4-1/3; allotype 1 male dissected on slides Nos. 4-2/1, 4-2/2, 4-2/3, 4-2/4. Paratypes 10 females and 1 male in spirit.

Geographical distribution.—Collected by K. J. Joseph from figs of *Ficus arnottiana* Miq. from Botanical Gardens, Trivandrum, 7-VII-1950.

Affinities. This species is closely related to *Blastophaga quadraticeps* Mayr but is readily distinguished from it as seen in the above description.

Blastophaga quadraticeps Mayr

1885. *Blastophaga quadraticeps*, MAYR, *Verh. zool.-bot. Gesellsch. Wien*, **35** : 176-177.
1923. *Blastophaga quadraticeps*, GRANDI, *Bull. ent. Res.* **13** : 296-297, fig. I.
1928. *Blastophaga quadraticeps*, GRANDI, *Boll. Lab. Ent. Bologna*, **1** : 123-126, fig. VII.

I refer to this species several females and males on slides and in spirit, collected by K. J. Joseph from the figs of *Ficus religiosa* Linn. from near the Railway Station, Trivandrum, Travancore, dated 12th July, 1950.

Blastophaga gestroi Grandi

1916. *Blastophaga gestroi*, GRANDI, *Boll. Lab. Zool. Portici*, **11** : 184-193, figs. I-IV.
1928. *Blastophaga gestroi*, GRANDI, *Bull. Soc. Zool. France*, **53** : 79.

I refer to this species several females and males, on slides and in spirit, collected by K. J. Joseph from the figs of *Ficus asperrima* Roxb. on way to Vazhapara Beat, Pathanapuram Taluk, Travancore, dated 25th June 1951.

Ceratosolen mysorensis, sp. nov.

Female.—Length 1.6 mm. General colour ferrugino-testaceous; antennae yellowish-brown, legs and ovipositor melleous, ovipositor valves yellowish-brown and black.

Head markedly longer than wide between the external margins of the eyes; lateral margin forwards of eyes a little less than one and a half times as long as the longitudinal diameter of the eye and slightly converging forwards; posterior margin behind the eyes rounded off laterally and visibly concave in the middle; ocelli three in an obtuse triangle; eyes large; the sublateral chitinised area of the frons with small hairs. Antenna (Fig. IV, 26) with eleven segments; scape as in figure, large, one and four-fifths as long as its maximum thickness, with a few small setae; second segment with a number of short, stout specialised, pointed setae all directed backwards; third segment strongly recurved, with three more strongly chitinised areas along its internal margin, with a setae, sensillae and a terminal spine as in figure; fourth segment a little longer than thick; fifth a little less than one and one-third as long as thick; length of sixth a little over twice its thickness; seventh a little less than twice as long as thick; eighth narrow basally, broad distally, one and one-fifth as long as thick; ninth, tenth and eleventh segments fused to form a large club about one and a half times as long as thick; the ninth distinctly thicker than

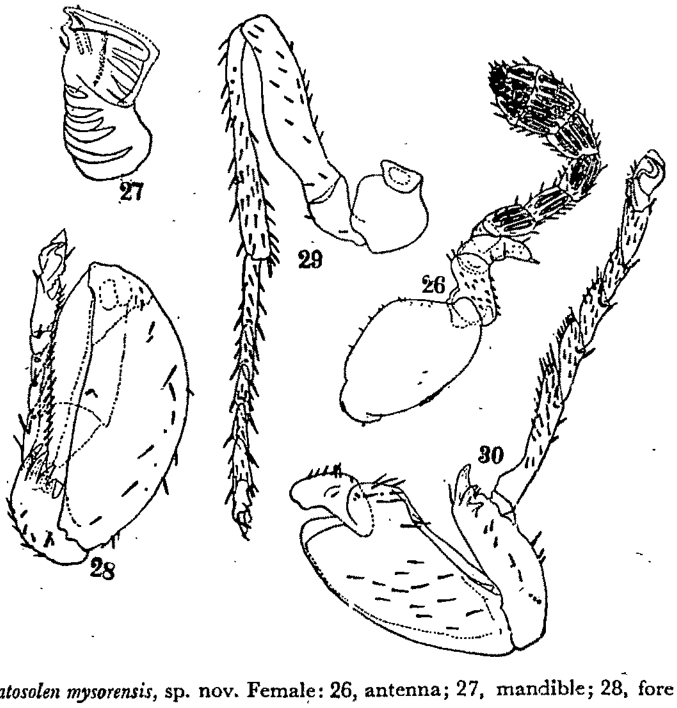

FIG. IV.—*Ceratosolen mysorensis*, sp. nov. Female: 26, antenna; 27, mandible; 28, fore leg; 29, mid leg; 30, hind leg.

long, its margins diverging towards apex; tenth thickest of all, about twice as thick as long, provided with a large clear ovoid area bearing about eight rounded sensillae as in figure; eleventh segment small; segments five to eleven with many large elongate sensoria and setae as in figure. Mandible (Fig. IV, 27) large and stout, wider than long, bidentate, apical tooth acute, with setae as in figure; appendage one and one-third as long as the mandible, about one and a half times as long as its own width, with five transverse ridges. Fore leg (Fig. IV, 28) with coxa a little less than two and a half times as long as thick; trochanter subtriangular, as long as thick; femur large, about two and one-fifth as long as thick, its dorsal margin convex and largely arched, with a few long setae; tibia twice as long as thick, strongly recurved, with setae and a four-dentate distal expansion as in figure; tarsi five-segmented, armed with numerous setae, metatarsus a trifle longer than half the total length of all the five tarsal segments combined, segments two, three and four short, their combined length being much less than that of the metatarsus, fifth segment two-thirds the length of the second, third and fourth segments combined; pretarsus with a pair of curved claws and the empodium. Mid leg (Fig. IV, 29) with coxa about as long as thick; trochanter a little more than half as thick as long; femur a little recurved, about four and a half times as long as its maximum thickness and with setae as in figure; tibia subclaviform, longer than the femur, about eight and a half times as long as its maximum thickness, with many long setae and a small-sized apical spur; tarsi five-segmented, longer than the tibia, armed with setae, metatarsus equal in length to the fore metatarsus and a little shorter than the second and third segments combined, fourth and fifth segments united about equal to the metatarsus; pretarsus with a pair of curved claws and the empodium. Hind leg (Fig. IV, 30) with coxa about one and a half times as long as its own thickness; trochanter twice as long as thick, with a few setae; femur large, compressed, one and two-thirds as long as thick, with dorsal and ventral margins and setae as in figure; tibia two and a half times as long as thick, a little recurved, with a complex bidentate process apically on the outer face and a large compressed odontoid spine apically on the inner face, with setae and sensillae as in figure; tarsi five-segmented, armed with setae, long, metatarsus longer than the combined length of the second and third segments; pretarsus with a pair of large curved claws and the empodium.

Abdomen about one and three-sevenths as long as high; seventh abdominal tergite with a pair of spiracles with large elongated peritremes; projecting part of terebra a little less than one and a half times as long as the abdomen.

Male.—Length 2.4 mm. General colour rusty red-brown; legs pale brownish-yellow; abdomen and antennae melleous; eyes black.

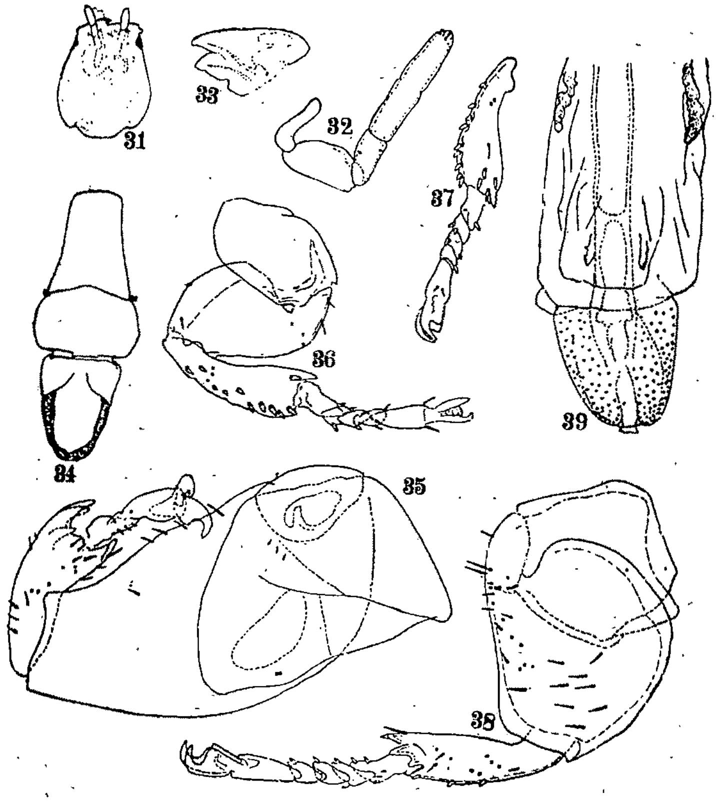

FIG. V.—*Ceratosolen mysorensis*, sp. nov. Male: 31, head; 32, antenna; 33, mandible; 34, thorax; 35, fore leg; 36, mid leg; 37, tibia and tarsi of mid leg, outer aspect; 38, hind leg; 39, details of eighth and ninth abdominal segments.

Head (Fig. V, 31). Length about one and one-third as long as its maximum width; lateral margins of head moderately convex in the posterior half, gradually converging forwards; postero-median margin of head distinctly convex; epistomal margin with a median angulose projection and two submedian projecting lobes; dorsum of head with extremely minute setae. Antenna (Fig. V, 32). Radicle rod-like, thicker at base, four times as long as thick; scape a little over twice as long as thick; second segment twice as long as thick; third longer and thicker than second, a little over twice as long as thick; fourth longer than third but less thick, length two and five-sevenths the thickness, gently narrowing towards apex where it is provided with a few short sensoria. Mandible (Fig. V, 53) distinctly longer than wide, bidentate, teeth as in figure.

Thorax. (Fig. V, 34). Pronotum a little less than one and a half times as long as its maximum width; lateral margins very faintly concave and converging forwards; posterior margin concave. Metanotum one and one-third as wide as long, lateral margins convex. Metanoto-propodeum subtriangular, about one and a half times as long as its maximum width; propodeum with a pair of spiracles with large peritremes which extend along its entire lateral margins. Fore leg (Fig. V, 35) with coxa large, a little less than one and a half times as thick as long; trochanter indistinct; femur very large, compressed, twice as long as thick and as in figure; tibia twice as long as thick, with setae and sensillae, distally with three large recurved odontoid processes on its outer face near the dorsal margin and two processes of the same type on its inner face near the ventral margin as in figure; tarsi two-segmented, the metatarsus shorter than the second tarsal segment and provided proximally with a distinct lobe and with setae; pretarsus with a pair of robust falciform claws. Mid leg (Fig. V, 36) with coxa about one and two-thirds as long as thick, glabrous; trochanter indistinct; femur large, a little less than twice as long as thick, glabrous; tibia recurved, a little over three and a half times as long as thick, with odontoid spines, setae and sensillae on its outer and inner faces as in figure V, 37 & 36 respectively; tarsi five-segmented, armed with short odontoid spines, metatarsus longest of all the tarsal segments, segment two a little longer than the third and the fourth segments which are equal, fifth longer than the second; pretarsus with a pair of robust falciform claws and the empodium. Hind leg (Fig. V, 38) with coxa about as long as thick, glabrous; trochanter indistinct; femur large, a little longer than thick, with a few setae and sensillae; tibia about four times as long as thick, with three small odontoid spines along its outer margin and with a few long setae and sensoria. Apically on the outer face the tibia shows a complex bidentate process. Tarsi as long as the tibia, five-segmented, armed with odontoid spines, metatarsus shorter than the fifth tarsal segment which is longest, second segment a little longer than the third and the fourth which are equal; pretarsus with a pair of robust falciform claws.

Abdomen large, about thrice as long as its maximum width, eighth tergite (Fig. V, 39) with a pair of spiracles provided with large linear peritremes; tenth segment with a pair of bilobed cerci of which the proximal lateral lobes bear no teeth, their distal lobes large and rounded off and with five or six dentiform processes.

Holotype 1 female dissected on slides Nos. 2-1/1, 2-1/2, 2-1/3; allotype 1 male dissected on slides Nos. 2-2/1; 2-2/2; 2-2/3 & 2-2/4. Paratypes 2 males in spirit.

Geographical distribution. Collected by K. J. Joseph from the figs of *Ficus mysorensis* Hayne from Botanical Gardens, Trivandrum, dated 12th July, 1950.

Ceratosolen marchali Mayr

1906. *Ceratosolen marchali*, Mayr, *Wien. ent. Zeitung*, **25** : 155-156.
1928. *Ceratosolen berlandi*, Grandi, *Bull. Soc. Zool. France*, **53** : 74-79, fig. II.
1928. *Ceratosolen marchali*, Grandi, *Boll. Lab. Ent. Bologna*, **1** : 173-176.

I refer to this species seven females and several males on slides and in spirit, collected by K. J. Joseph from the figs of *Ficus hispida* Linn. from Baker Memorial School Compound, Kottayam, Travancore, dated 26th June, 1951

Eupristina grassii Grandi

1916. *Eupristina grassi*, Grandi, *Boll. Lab. Zool. Portici*, **11** : 218-225, figs. XII-XIV

I provisionally refer to this species* several females and males on slides and in spirit, collected by K. J. Joseph from the figs of *Ficus bengalensis* Linn from the Botanical Gardens, Trivandrum, Travancore, dated 15th June 1950.

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*Saunders, *Trans. ent. Soc. London*, 1883, pp. 6-7, pl. I, figs. 1-15.

My observations correspond to that of Grandi (loc. cit.) except for the following:—(i) mandibular appendage in the female with five tooth-like projections internally; (ii) the post coxa in the male a little less than one and a half times as wide (thick) as long.

MUSCULATURE OF *MYLABRIS PUSTULATA* THUNB. (COLEOPTERA)*

By O. N. SAXENA M. Sc., Ph. D., *Lecturer in Zoology, Maharana Bhupal College, Udaipur (Rajasthan).*

This paper deals with descriptive morphology of the musculature of *Mylabris pustulata.* Considerable amount of work has been done on musculature of insects in recent years, but no comprehensive account is available on an Indian type for use in universities. I have followed in the main the terminology of Straus-Druckheim (7) and Bauer (1).

I thank Prof. M. S. Mani for facilities for work and guidance.

MUSCULATURE OF THE HEAD

The cephalic muscles include : 1. The intrinsic muscles of the head. 2. The extrinsic muscles of the head.

Intrinsic muscles of the head.—The intrinsic cephalic muscles have their origin and insertion within the head and they serve to move parts of the head. They include : I. the antennal, II. the gnathal and III. the stomodaeal muscles.

Antennal muscles

Extrinsic muscles.—The antennae as a whole are moved by a set of three extrinsic muscles arising from the tentorium.

An antennal *flexor* muscle (1 in Fig. 1) arises dorsally from the tentorium and converges to its insertion mesially on base of the scape of the antenna. When this muscle contracts, the two antennae are brought towards each other.

An antennal *extensor* (2) which is the antagonistic of the flexor of antenna, arises dorsally and posteriorly on the tentorial arm and comprises nearly parallel bundles of fibres that are inserted externally on the base of the antennal scape. Its contraction moves the two antennae away from each other.

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An antennal *rotator* (*3*) is a slender muscle that arises ventrally from the tentorial arm and is inserted ventrally on the base of the antennal scape. Its contraction depresses the antenna.

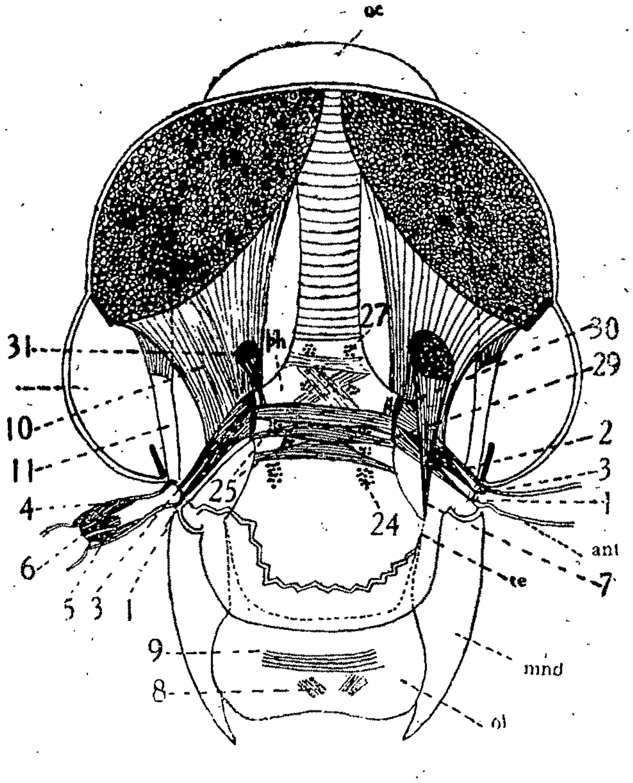

Fig. 1. Musculature of the head. (× 20) **1.** antennal flexor; **2.** extensor; **3.** rotator; **4.** adductor; **5.** abductor; **6**. depressor; **7.** labral retractor; **8.** compressor; **9.** intrinsic labral muscle; **10.** mandibular adductor; **11**. abductor; **24, 25, 27.** anterior dorsal stomodaeal dilators **29, 30**. lateral stomodaeal dilators; **31**. retractor of mouth angle; *ant.* antenna; *mnd.* mandible; *oc.* occiput; *ol.* labrum; *ph.* pharynx; *te.* tormae.

Intrinsic muscles.—The intrinsic muscles of the antennae include an *adductor* (*4*), an *abductor* (*5*) and a *depressor* (*6*) of the pedicel.

The adductor arises on the outer side of the distal end of the scape and is inserted on the outer side of the base of pedicel; the abductor arises on the inner side and is inserted on the inner side of the pedicel while the depressor arises from between the adductor and abductor and is inserted between the insertion points of the last two muscles.

The presence of three intrinsic muscles is not found in other beetles. Bauer (1) and Khatib (4) in the descriptions of antennal musculature of *Dytiscus* and *Galerucella* respectively have described only two intrinsic muscles viz. antennal abductor and adductor. Pradhan (5) in the description of the mouth parts of *Coccinella* has not described but has figured only two muscles and labelled them as intrinsic antennal muscles.

Gnathal muscles

The gnathal muscles comprise the extrisnic and intrinsic muscles of the *labrum-epipharynx*, the *paired mouth parts* and the *labium hypopharynx*.

Muscles of the labrum-epipharynx.—The extrinsic musculature of the labrum consists of only a single pair of muscle (*7* in Fig. 1). They originate from frons and are inserted on the *tormae* (*te*) of the labrum. The cotraction of these muscles is capable of effecting (i) elevation or retraction of the labrum (ii) lateral movements of the labrum. The movements depend whether both the muscles of the pair contract simultaneously or each of them separately.

Pradhan (5) has also described a pair of extrinsic muscles but their insertion is not the same as in *Mylabris*. There they are inserted on the basal angles of the anterior sclerotized wall of the labium and not on the tormae. Bauer (1) also describes of a pair of similar muscles and has called them as *labral levator*.

The intrinsic musculature of the labrum consists of two sets of fibres. A pair of short labral *compressor* muscle (*8*) arising on the inner surface of the labrum and inserted on the epipharynx, constitutes one of the chief intrinsic labral muscles.

The contraction of these muscles flattens out the labrum epipharynx. A third set of intrinsic labral muscles (*9*) comprises a bundle of fibres arising laterally on the inner surface of the labrum, passing transversely to be inserted on the other side of the labrum. The contraction of this muscle increases the curvature of the labrum in the lateral plane. Such intrinsic muscles have also been described by Pradhan (5) and Dass (2). Bauer (1) states that there are no intrinsic labral muscles in *Dytiscus*.

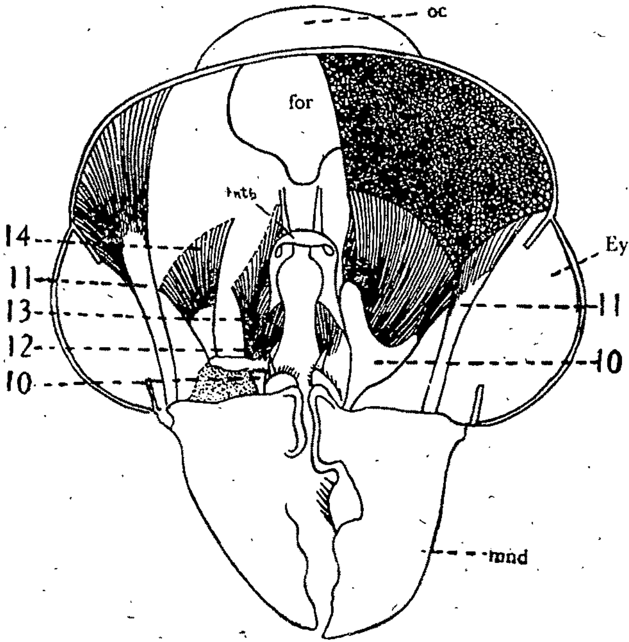

Fig. 2.— Musculature of the head; deeper muscles (×20). **10.** mandibular adductor; **11.** abductor **12, 13, 14.** ventral flexor, dorsal flexor and extensor respectively of maxilla; *for.* foramen magnum; *mnd.* mandible; *oc.* occiput; *tntb.* tentorial bridge.

Muscles of the Mandible.—The mandible is moved by a pair of extrinsic muscles and there is no intrinsic muscle within the mandible. A large, stout and very powerful mandibular *adductor* (*10* in Figs. 1, 2) or flexor arises from an extensive area of the cranial wall. It is really composed of two separate bundles, a dorsal and ventral. It is inserted on a large sclerotized mandibular apodeme from the mesial angle at the base of mandible. Its contraction brings the two mandibles together and serves to crush and grind the food. Its antagonist is a small mandibular *abductor* (*11*) or extensor muscle that arises from the surface of the occiput and is inserted externally on the mandibular base by a small apodeme. The abductor moves the mandibles outward; in other words it opens jaws.

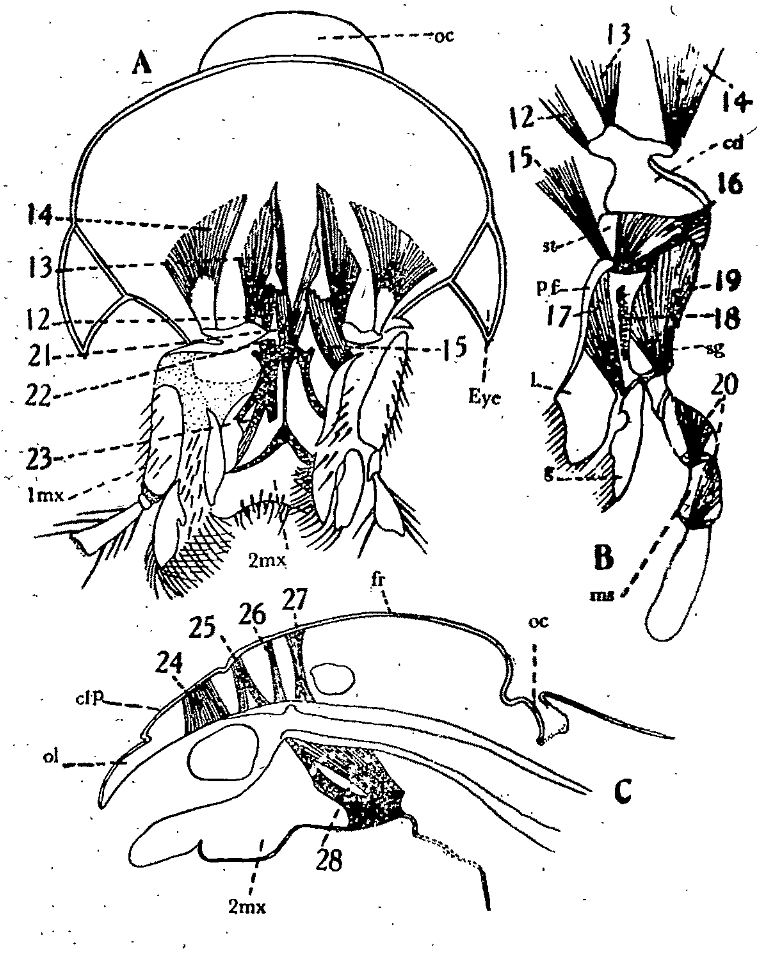

FIG. 3. Musculature of the head A. Muscles of the maxilla and labium in situ. (× 20) B. Intrinsic and extrinsic muscles of the maxilla. (× 20) C. Stomodaeal dilators. (×20) (**12**). ventral flexor of maxilla; (**13**). dorsal flexor; **14**. extensor; **15**. tentorial flexor of lacinia;. **16, 17, 18**. stipital flexors of lacinia, galea and maxillary palpus respectively; **19, 20**. stipital extensor and flexor muscles respectively of maxillary palpus; **21**. levator of labium ; **22**. retractor of prementum; **23**. flexor of labial palpus; **24, 25, 26, 27**. dorsal stomodaeal dilators; **28**. ventral stomodaeal dilators; *cd.* cardo; .clypeus; *fr.* frons; *g.* galea; l. lacinia; *ms.* maxillary palpus; *oc.* occiput; *ol.* labrum; *of.* palpifer; *sg.* subgalea; *st.* stipes; *lmx.* maxilla; *2mx.* labium.

Muscles of the Maxilla.—The maxilla is provided with both extrinsic and intrinsic muscles.

There are four extrinsic muscles that move the maxilla as a whole. Three of these muscles (*12*, *13*, *14* in Fig. 2, 3 AB) are inserted on the cardo and one (*15*) on the lacinia. Two of them (*12*,*15*) arise wholly on the tentorium, one (*13*) partly on the tentorium and partly on the cranial wall and one (*14*) wholly on the cranial wall. A *ventral flexor of maxilla* (*12*) arises on the tentorium laterally outside and is inserted mesially on the base of cardo. A *dorsal flexor* of maxilla (*13*) arises partly from the tentorium and partly from the cranial capsule nearby and is inserted likewise on the base of cardo but somewhat externally to the ventral flexor. The *extensor* of maxilla (*14*) arises from the cranial wall below the eye and is inserted basally outwards on the cardo. A *tentorial flexor of lacinia* (*15*) arises on the inner margin of the tentorium and is inserted basally on the lacinia. By the contraction of these muscles maxilla moves inward, backward and outward, depending upon whether one muscle or all the muscles contract.

The intrinsic muscles of the maxilla include a *stipital flexor of lacinia* (*16* in Fig. 3 B) that arises from the inner surface of the base of stipes and converges to be inserted on the base of lacinia above the tentorial flexor of lacinia. A *stipital flexor of galea* (*17*) arises from the inner mesial surface of stipes and converges to its insertion basally on the subgalea. A *stipital flexor of maxillary palpi* (*18*) arises broadly from the ventral surface of stipes to be inserted dorsally and mesially on the palpiger. The *stipital extensor* of maxillary palpi (*19*) arises from the palpiger and is inserted basally outside on the first palpal segment. It is a strong fan-shaped muscle that moves the palpus outwards. There is no antagonistic muscle to this. The palpus therefore comes back to the original position by the elasticity of chitin. The intrinsic muscles of the palpus are found in the segments except the basal and apical. The third and fourth segments have each a *flexor* muscle (*20*) arising respectively in the second and third segments and inserted basally and mesially on the third and fourth segments. If they contract the palpal segment moves inwards.

When the maxillary muscle of *Mylabris* are compared with those of *Dytiscus* and *Coccinella* many differences are noticed. There are only four extrinsic muscles in the maxilla of *Mylabris* and *Dytiscus*, while in *Coccinella* there are five. *Mylabris* differs both from *Coccinella* and *Dytiscus* in the insertion of one extrinsic muscle on lacinia. In *Dytiscus* and *Coccinella* no extrinsic maxillary muscle is inserted on the lacinia. There are some differences in the origin of extrinsic muscle. Usually they arise from the cranial wall. The actual places of origin always vary in different species. However in *Mylabris* there are two extrinsic muscles (*12*, *15*) which originate wholly or partly from tentorium, while in *Coccinella* there is only one such muscle, i. e. ventral flexor of maxilla. In *Dytiscus* no extrinsic muscle arises from tentorium. When the intrinsic musculature is compared, it is noticed that *Mylabris* has one muscle more than in *Dytiscus* and *Coccinella*, which have four each. The differences are due to the different ways of sclerotization of maxillay sclerites, which in turn are correlated to feeding habits.

Muscles of Labium.—The labium is moved as a whole by a pair of *levator muscles* (*21* in Fig. 3 A) that arise on the tentorium and extend forward and inward to be inserted on a common long apodeme from the distal sclerotized ridge of prementum. When these contract, the labium is raised. A pair of parallel bundles of muscles arise from an apodemal inflection at the base of the postmentum and slightly extend mesad to be inserted basally on the prementum. These serve as *retractors* of the prementum (*22*). A pair of *flexors of the labial palpi* (*23*) arise from basal sclerotized rod of postmentum and are inserted mesially on the base of the palpifer. It moves the palpus outwards. The labial palpi and the ligula have no intrinsic muscles.

When compared with *Dytiscus* the musculature shows reduction in muscle number because in *Mylabris*, the paraglossa and glossa have fused together, while in *Dytiscus* the labium is strongly modified and therefore the musculature is of a specialized type. There are levator of glossa and paraglossa which have a common antagonist—the depressor of glossa. These are absent in *Mylabris*. The other difference is the origin of levator of labium, which is a long muscle in *Dytiscus* originating from the lower margin of the foramen magnum, while in *Mylabris* it arises from the tentorium. It shows certain advancements in the possession of extrinsic muscles which are absent in *Coccinella*. There is no premental muscle in paraglossa as found in *Coccinella*.

Stomodaeal muscles

The cephalic part of stomodaeum is provided with *dilator muscles* (*24-28* in Fig. 3C) which arise on the cranial wall and tentorium. The former are here termed as *anterior-dorsal dilators*, as they arise on clypeus and frons in front of the brain. The first pair of these (*24* in Fig., 3C) is a thick bundle that arise on the clypeus and are inserted on the epipharyngeal wall of the cibarium anterior to the oral opening just in front of the first band of circular muscles. It is called *cibarial dilator*. The second pair of muscles (*25*) originates from frons just behind the epistomal suture. It is inserted on the pharynx at two places with circular muscle bundles in between the insertion points. The third pair (*26*) is a thin bundle originating on frons behind *25* and inserted on the pharyngeal wall just in front of the frontal ganglion. Similar muscles (*25*, *26*) have been termed *pharyngeal dilatores frontales* by Pradhan (5). A fourth pair of muscle bundle (*27*) originates from frons and is inserted on the pharynx. It is dumb-bell-shaped, narrow in the middle and broad at the point of origin and insertion. As they are situated just behind the frontal ganglion, they can be termed as *dilatores pharyngis postfrontales*. A pair of *ventral dilators* (*28*) arise on the base of the tentorium and are inserted ventrally on the pharyngeal wall. They are narrow at the place of origin but broad at the point of insertion. They do not run perpendicularly between the pharynx and tentorium as do the dorsal dilators but are somewhat oblique, making an acute angle with anterior ventral cranial wall. The action of these muscles is similar to that of dorsal dilators. Pradhan (5) mentions that ventral dilators are absent in *Coccinella*. There is a pair of *retractors of the mouth angle* (*31* in Fig. 1), which arise from dorsal wall of the cranium and are inserted on what has been described by Snodgrass (6) as the oral branches of the suspensorial sclerites of the hypopharynx. Contraction of these muscles raises the floor of the pharynx.

Two pairs of *circular muscles* (*29, 30*) situated behind the dorsal dilators (*25*) run transversly on the dorsal surface of the pharynx but are also attached on the lateral sides with the dorsal arm of the tentorium. These are the *compressor muscles* of the pharynx. Their attachment with the tentorium is a special feature which has not been described in any other beetle.

MUSCULATURE OF THE THORAX

Prothoracic Musculature.—The musculature of the prothorax includes:

1. the extrinsic muscles of the head that take their origin within prothorax and move the head as a whole.
2. the flight muscles.
3. the muscles of the legs.

Extrinsic Muscles of Head.—The head can be moved freely in all directions and has therefore a well developed musculature viz. levators, depressors and rotator muscles. All these muscles are inserted close to the occipital foramen and have their origin in prothorax or anterior margin of mesothorax. The superior rotator of the head is the strongest muscle.

The *horizontal levators of the head* comprise two bundles (*32, 33* in Fig. 4A) of muscles inserted on an apodeme from the dorsolateral margin of the occipital ring of the head. One of these bundles (*32*) arises from the anterior surface of the phragma of mesothorax, passes through the whole of prothorax to its place of insertion. The second bundle (*33*) arises laterally from the median longitudinal apodeme from pronotum and runs outward and forward to its place of insertion. Contraction of muscles of one side rotates the head in that side and the contraction of the muscles of the two sides raises the head. In *Dytiscus* it is a single bundle on each side and is much shorter because of the smaller prothorax. The *horizontal depressors* of the head (*34*) arise from the prosternal apophyses, pass forward to be inserted ventrally on the occipital rim. Contraction of these muscles lowers the head. It is not the strongest muscle of the head as in the case of *Dytiscus*. *Superior rotator* of the head (*35* in Fig. 4AB) arises on pronotum, with broad bases one on either side of the medial longitudinal apodeme and is inserted ventrolaterally on the occipital rim by a broad chitinous tendon. It is the strongest muscle of the head. Contraction of the muscle of one side turns the head to that side and the contraction of muscle of both the sides moves the head downwards. In *Dytiscus* it is a small fan-shaped muscle. *Vertical levators* of the head (*36*, *37*) are inserted dorsolaterally on an apodeme from the occipital rim. They comprise two bundles : one of these bundles (*36*) arises anteriolaterally on pronotum and the other (*37*) from the cervical sclerite. In addition to these direct extrinsic muscles, the head is also moved indirectly by two muscles (*38*, *39*) inserted on the cervical sclerites. One of these arises from the prosternal apophyses and the other anterolaterally from the pronotum. These muscles are connected to the head through the cervical sclerites and function variously as the levators, depressors, retractors, protractors and rotators of the head. In *Dytiscus* there is no such indirect connection of the muscles with the head.

Muscles of the foreleg. – The movement of the leg as a whole, in relation to the thorax takes place at the articulation of coxa. This is similar in the case of fore and midleg but is totally different in the case of hindlegs because free movement is not possible here. This is because the coxa is very closely united with the preepisternum. The free movement is possible only at the articulation of trochanter.

The extrinsic muscles of the foreleg arise within the prothorax. A *tergal promotor of leg* (*40* in Fig. 4ABC) arises from pronotum just by the side of median plate as a thin

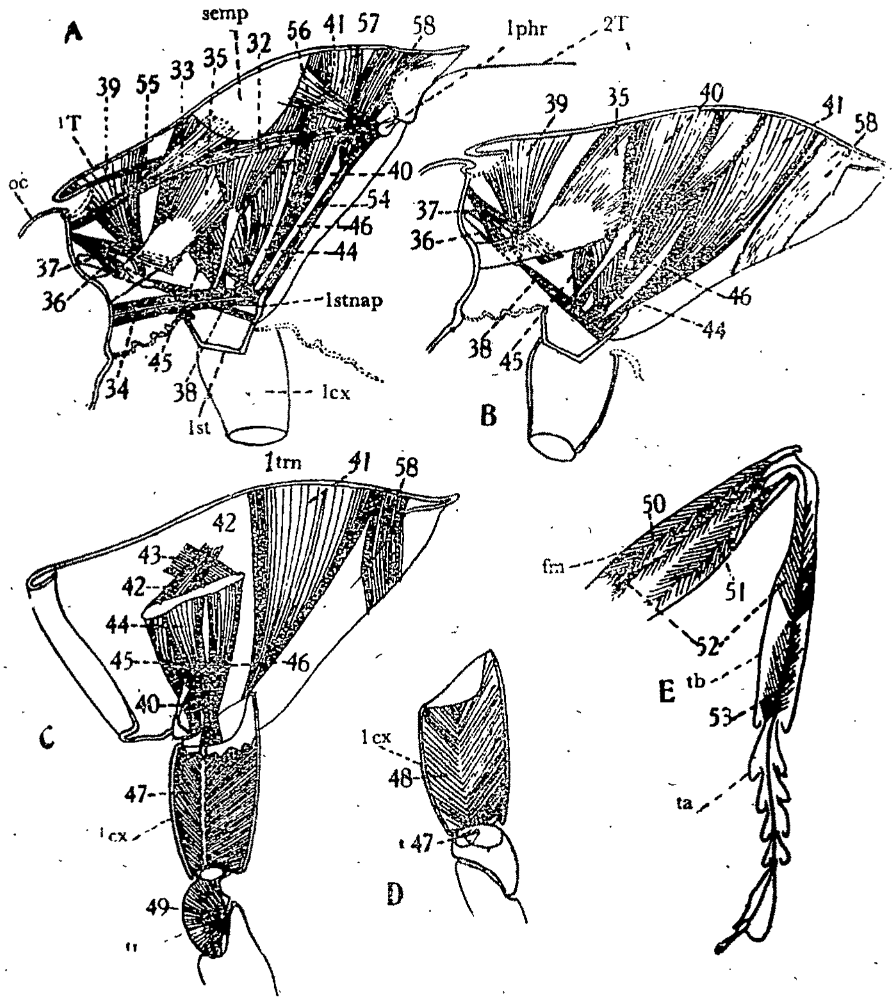

FIG. 4. Muscles of prothorax and its legs A. Superficial muscles of prothorax seen from the left. (X 17) B. Deeper muscles of prothorax seen from the left. (X 17) C. Extrinsic muscles of the foreleg. (X 17) D, E. Intrinsic muscles of the foreleg. (X 17) **32, 33.** horizontal levators of head ; **34** ; horizontal depressor of head ; **35.** superior rotator of head ; **36, 37.** vertical levator of head ; **38, 39.** indirect cephalic muscles ; **40.** tergal promotor of leg ; **41.** tergal remotor of head ; **42, 43.** anterior and posterior notopleural muscles respectively ; **44. 45.** pleural adductor and abductor respectively of leg ; **46.** depressor of trochanter ; **47.** depressor of leg ; **48.** levator of leg ; **49.** reductor of femur ; **50, 51.** flexor and extensor respectively of tibia ; **52, 53.** flexor of claw and tarsus respectively ; **54.** lateral intersegmental muscle ; **55.** lateral longitudinal muscle ; **56.** dorsal longitudinal ; **57.** lateral oblique ; **58.** rotator of prothorax ; t47. tendon of the depressor of the leg ; *fm.* femur ; *oc.* occiput ; *semp.* endoskeletal plate of pronotum ; *ta.* tarsus ; *tb.* tibia ; *tr.* trochanter ; *1cx.* coxa of the prothoracic leg ; *1phr.* phragma of mesothorax ; *1st.* prosternum *1stnap*- prosternal apophysis ; *1trn.* trochantin of foreleg; *1T.* pronotum; *2T.* mesonotum-

but broad muscle and is inserted on the trochantin by a long tendon. It draws the leg forward and inward. The *tergal remotor of coxa* (*41*) is the largest of extrinsic muscles, very broad at its origin. It arises posterolaterally on pronotum and is inserted on the coxal condyle. It moves the leg backward. The *anterior and posterior notopleural muscles* (*42, 43* in Fig. 4C) extend from the pronotum to the trochantin. They are short but stout muscles which cross each other and are inserted on the dorsal wall of the trochantin. They give a firm attachment to trochantin with pronotum so that when muscles *44, 45* and *46* contract, the position of the trochantin is not disturbed. The *pleural adductor of leg* (*44* in Fig. 4ABC) extends from the mesial part of trochantin to the mesial rim of coxal base. The *pleural abductor of leg* extends from the trochantin (lateral aspect) to the outer aspect of the coxal rim (*45*). Its contraction moves the coxa inwards. The *extra-coxal depressor of trochanter* (*46*) arises on the trochantinal plate and passing through the cavity of coxa is inserted on a large apodeme in the trochanter. By the contraction of this muscle the leg is moved from above downward thereby the body is raised from the surface thus contributing to chief movement of climbing.

The intrinsic muscles of the leg. The *depressor of the leg* (Fig. 4CD. *47*) arises mesially (ventrally) within the coxa and is inserted on the same apodeme as that of the insertion of the extracoxal depressor of trochanter. The *levator of leg* (*48* in Fig. 4D) arises dorsally (outer aspect) in coxa and is inserted laterally (dorsally) on trochanter. The *reductor of femur* (*49* in Fig. 4C) is a diverging bundle of muscles arising within the trochanter and inserted posteriorly on the base of femur. This muscle has been called *rotator of femur* by Bauer (1) in *Dytiscus*. It rotates the femur. A *flexor & extensor of tibia* (*50, 51* in Fig. 4E) arise inside the femur and are inserted basally on tibia. Both the muscles are long and occupy nearly the whole length of femur. They are composed of small muscle fibres attached on a median tendon like the barbs of a feather. They stretch and bend the tibia respectively. The *flexor of the claw* (*52*) arises posteriorly within the femur. It has a thin tendon which passes through the femero-tibial articulation into the tibia and combines with the tendon of another muscle arising within tibia. The common tendon passes through all the serial segemts of tarsus which are devoid of muscles and is finally inserted on a long thread-like apodeme arising from the unguitractor plate in pretarsus. An *extensor of tarsus* (*53*) arises from the distal end of tibia and is inserted on the base of metatarsus. It bends the entire tarsus. There is no antagonist of this muscle.

The prothorax contains in addition the muscles, which move the prothorax with reference to mesothorax. *Lateral intersegmental muscles* (*54* in Fig. 4A), one on either side, arising externally from prosternal apophyses and inserted on the outer aspect of mesophragma at the point of origin of the horizontal levator of head mentioned above. It is a cylindrical muscle bundle connecting the mesonotum with prosternum. It runs obliquely and acts as depressor of prothorax. When it contracts, the sternal region is raised and this depresses the anterior part of the compact pronotum. *Lateral longitudinal muscles* (*55*) extend from the phragma of the mesothorax to the anterior margin of pronotum. It is the longest muscle in the prothorax whose muscle fibres are indirectly connected with the *horizontal levators of the head* (*32*). If the muscle of one side contracts, the prothorax is turned to that side and if the muscles of both sides contract, the prothorax is retracted. Usually it is used as a retractor and hence also called *dorsal retractor of prothorax*. The *median dorsal longitudinal muscles* (*56*) extend from the mesophragma to the posteromedian part of the pronotum. It is small but thick muscle bundle. The *lateral oblique muscles* (*57*) are a stout pair arising lateroventrally from the anterior margin of the phragma of mesothorax, passing upward and forward as a diverging bundle to be iserted on the pronotum laterad of the place of insertion of the median oblique dorsal muscles. Both these muscles act as levator and rotator of prothorax. If both the pairs are pulled together then the prothorax is retracted as a whole over the mesonotum. If muscles of only one side contract then the prothorax is turned to back side.

The muscles of mesothorax.—The muscles of the mesothorax comprise the dorsal and ventral longitudinals, and the dorsoventrals that move the leg and are modified and greatly enlarged to serve as flight muscles. There are comparatively very few muscles inserted directly on the base of the wing.

A *rotator of prothorax* (*58* in Figs. 4ABC, 5A) originates medially from the anterior mesepisternum and is broadly inserted on

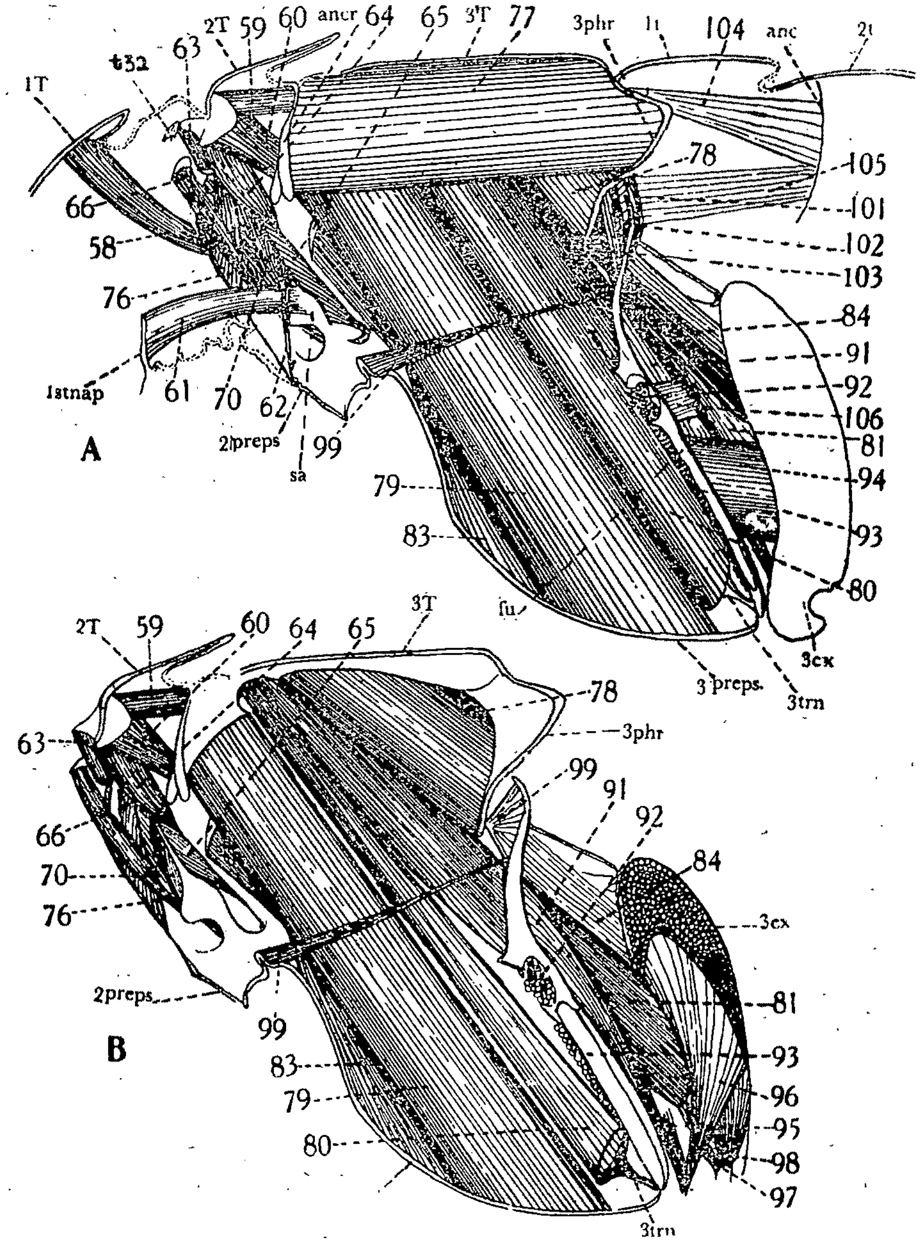

FIG. 5. Musculature of pterothorax. A. Superficial muscles viewed from the left. (X17) B. The same after removal of some of the bundles. (X17) **58.** rotator of prothorax; **50, 60** median dorsal and lateral dorsal longitudinal muscles respectively; **61.** ventral longitudinal muscle; **62.** muscles of odoriferous glands; **63.** levator of elytra;

64. tergal flexor of coxa; **65.** sternal flexor of coxa; **66.** tergal promotor of coxa; **70.** depressor of leg; **76.** depressor of elytra; **77.** median dorsal longitudinal muscle; **78.** lateral dorsal longitudinal muscle; **79.** anterior lateral muscle; **80.** median lateral levator of wing; **81.** levator of coxa; **83, 84.** anterior and posterior extensors respectively of wing; **91.** extracoxal flexor of leg; **29, 93, 94.** furco-coxal muscles; **95, 96, 97, 98.** intrinsic muscles of hind leg; **99.** sterno-pleural muscles; **101, 102, 103.** furco-dorsal muscles; **104, 105.** extrinsic muscles of abdomen; **106.** abdominal conjugant muscle; t32. tendon of horizontal levator of head. **anc.** antecosta; **ancr.** antecostal ridge; *fu.* furca; *sa.* sternal apophysis of mesothorax; *3 cx.* coxa of hind leg; *3phr.* posterior phragma of metathorax; *2preps, 3preps.* pre-episternum of meso and metathorax respectively; *1stnap.* prosternal apophysis; *1t, 2t.* first and second abdomenal terga respectively; *1T, 2T, 3T.* pro, meso and metanotum respectively; *3trn.* trochantin of hind leg;

the posterior dorsal surface of pronotum. It runs obliquely from below upwards. A *median dorsal longitudinal muscle* (*59* in Fig. 5) stretches as a small but compact muscle one on either side of the mid-dorsal line from the mesophragma to the acrotergite of the metathorax and slightly diverging in front. This corresponds to the *horizontal levator of the head* in the prothorax. When it contracts, the anterior margin of mesonotum is drawn downwards and the scutellum is thus raised, releasing the scutellar catch on the base of elytra. Only after this catch is released, the elytra can be opened out for flight. The paired *lateral dorsal longitudinal muscles* (*60*) extend from the mesophragma to the lateral processes of prescutum of metathorax. This muscle supports the action of the median dorsal. The *ventral longitudinal muscles 61* in Fig. 5A) extend between the mesosternal apophyses (arising on its base) and the prosternal apophyses on which the bundles are inserted on the entire posterior area. These muscles lie one on either side of the ventral nerve cord. They act as ventral retractor of prothorax. A muscle of this group (*62*) from mesofurca passes downward, forward and mesad to its insertion anteriorly on mesosternum. It opens the orifice of the duct of the paired odoriferous glands in mesothorax. A muscle arising from the sclerotized processes dorsally on the mesopleural ridge and running upward, forward and inward to be inserted on the mesophragma serves as the *levator of elytra* (*63* in Fig. 5AB). Contraction of this muscle raises the elytra after the scutellar catch has been released, ready to be opened out for taking off.

Muscles of the midleg.—The *tergal flexor of coxa* (*64*) arises posteriorly on mesophragma. It runs backward, downward and inward to its place of insertion on an apodeme from the base pos-

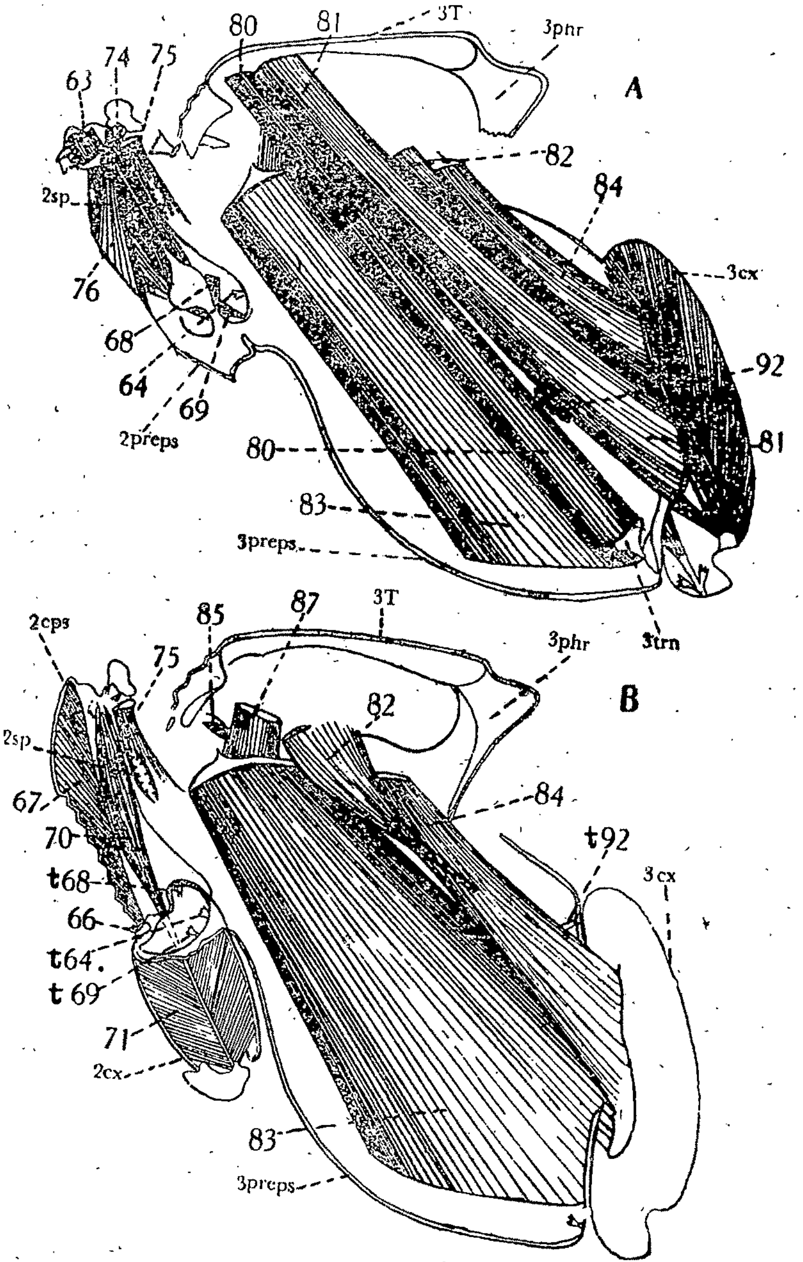

FIG. 6. Musculature of pterothorax. A. Deeper muscles viewed from the left. (X17) B. Same after removal of some bundles. (X17) **63.** levator of elytra; **64.** tergal flexor of coxa; **66.** tergal promotor of coxa; **67.** abductor of leg; **68.** sternal remotor of coxa; **69.** adductor of coxa; **70.** depressor of leg; **71.** flexor of trochanter; **74.** depressor of elytra; **75.** pleuro-basalare muscle; **76.** depressor of elytra; **80.** median-lateral levator of wing; **81.** levator of coxa; **82.** tergal flexor of coxa; **83, 94,** anterior and posterior extensor respectively of wing; **85.** relaxator-extensor muscle; **87.**

relaxator of extensor of wing; **92.** furco-coxal muscle; t64. tergal-flexor of coxa; t68. tendon of sternal remotor of coxa; t69. tendon of the adductor of coxa; t92. tendon of the furco-coxal muscle. *2cx, 3cx.* coxae of mid and hind legs respectively; *3phr.* posterior phragma of metathorax; *2preps, 3preps.* pre-episternum of meso and metathorax respectively; *2sp.* second thoracic spiracle; 3*T.* metanotum; 3 *trn.* trochantin of hind leg.

teromesially of coxa of midleg. Contraction of these muscles draws the legs together. With the legs fixed, they function as the *extensor of elytra*. The *sternal flexor of coxa* (*65*) arises mesially on the mesosternal apophyses, passes downward and backward to be inserted on the same apodeme as that of *tergal flexor of coxa* (*64*). The *tergal promotor of coxa* (*66* in Figs. 5, 6B) extends from the basalare sclerite to an apodeme from the dorsal side of trochantin. Contraction of this muscle moves the leg forward. The *abductor of leg* (*67* in Fig. 6B) arises on the episternum and is inserted on the same apodeme as *tergal promotor of coxa* (*66*). The *sternal remotor of coxa* (*68* in Fig. 6) likewise arises from the mesosternal apophyses posteroventrally and is inserted posterolaterally on base of coxa. The contraction of this muscle moves the leg backward. Another *adductor of coxa* (*69*) arises posterolaterally on mesosternal apophyses and is inserted mesially on base of coxa. The *depressor of leg* (*70* in Fig. 5, 6B) which also functions as the flexor of trochanter arises partly from mesepisternum and partly from mesosternal apophyses, passes through the coxa to be inserted basally and ventrally on trochanter. The *coxal branch of the flexor of trochanter* (*71* in Fig. 6B) serving as the depressor of leg arises within the coxa mesially and is inserted on the same point as the above mentioned muscle (70). The *sternal promotor of leg* (*72* in Fig. 7A) arises from the mesosternal apophyses and is inserted on an apodeme anteriorly on base of coxa. The *coxal extensor of trochanter* (*73*) arises dorsally (laterally) in the coxa and is inserted dorsally on base of trochanter. This functions as the levator of trochanter. The remaining intrinsic muscles of the midleg include the *reductor of femur*, the *flexor and extensor of tibia*, *flexor of claw* and *flexor of tarsus*. Their origin and insertion are similar to those of the forelegs. Among the remaining muscles of the mesothorax are: the *depressor of elytra* (flexor of elytra) (*74* in Fig. 6A) arising posteriorly on a process above the pleural ridge and inserted on the second axillary sclerite. This is a direct flight muscle. Its contraction brings back the elytra on the dorsum. The *pleuro-basalare muscle* (*75* in Fig. 6) is a weak bundle of fibres arising on the basalare sclerite and extending backward round the upper margin of the second thoracic spiracle and ending behind in a long thin colourless apodeme from the muscle disc of metapleuron. They help in folding the elytra. A muscle arising from mesepisternum and inserted likewise on the second axillary sclerite functions as the *depressor of elytra* (*76* in Figs. 5, 6A) in conjnuction with the one already mentioned.

In *Mylabris* there are more elytral muscles than in *Dytiscus*. In the latter the only muscles in this connection are the levator and depressor of elytra, superior and inferior mesonotal muscles which act as indirect muscles and the coxal extensor of mesothorax which act as direct muscle. Further these muscles of *Mylabris* are more developed and stronger than those of *Dytiscus*. This may be correlated with the differences in flying habit. *Mylabris* is a better flier than *Dytiscus*.

Metathoracic musculature.—The metathoracic muscles comprise the direct and indirect flight muscles, the muscles of leg and extrinsic muscles of abdomen. The extrinsic muscles of the leg also function as indirect flight muscles. Very few and feeble muscles are inserted directly on wing base or the wing base sclerites in comparision to the stout and powerful longitudinal and dorsoventral muscles that move the wing indirectly.

The flight muscles include the following:—

Median dorsal longitudinal muscles (*77* in Fig. 5A) stretching mesially between the anterior and posterior phragmata of the metathorax function as the depressor of wing. They are mostly highly developed muscles. When they contract, the metanotum is strongly arched upward and the wing is lowered. The *posterior lateral dorsal longitudinal muscles* (*78* in Fig. 5) function as the posterior levator of the wing. These lie behind and below the posterior half of the foregoing muscle. Arising from the posterior phragma of metathorax, ascend upward, forward and mesad to be inserted on the metanotum. These muscles are the antagonists of the first, because when they contract, the upcurved metanotum is flattened out and thus the wings are raised up. The *anterior lateral muscles* (*79*) are stout bundles passing latero-anteriorly from the perescutum to pre-episternum. The contraction of this muscle also flattens out the curvature of metanotum and thus this is the *anterior levator of wing.* The *median lateral levator of wing* (*80* in Fig. 5, 6A) arises by two bundles arising partly from the trochantinal disc and partly from posterior area of pre-episternum to be inserted on the antero-lateral part of scutum. The *levator of coxa* (*81*), arising behind the above mentioned muscles (*80*) and inserted laterally on basal apodeme of coxa, also serves to raise the wing. The *tergal flexor of coxa* (*82* in Fig. 6) stretching between the scutum near the posterior notal wing process and a long apodeme mesially on coxal base functions as levator of wing. The *anterior extensor of wing* (*83* in Figs. 5, 6, 7A) is a stout muscle arising partly from the lateral margin of coxal base and partly on pre-episternum and inserted in bell-shaped muscle disc dorsally on episternum. The *posterior extensor of wing* (*84* in Figs. 5, 6, 7A) passes from the lateral margin of coxal base to a cup-shaped muscle disc on epimeron. The *relaxator extensor muscle* (*85* in Fig. 7A) is a very small muscle bundle and extends between the basalare sclerite and the pleural ridge of metathorax. The *relaxator of wing* (*86*) is also a very small muscle bundle which passes between the muscle disc on metepimeron and the dorsal process of metepimeron. A small but short muscle passing between the muscle disc of episternum and scutal area behind the anterior notal wing process also functions as the *relaxator of extensor of wing* (*87* in Fig. 6B). The *flexor of wing* is an insignificant muscle and comprises a bundle (*89* in Fig. 7A) passing between the subalare sclerite and the pleural ridge and another bundle (*88*) from the subalare sclerite to the episternum. These bring about the closing of the wing at the end of flight.

The leg is moved by a series of muscles arising from the furca and inserted on different parts of the base of coxa. A muscle arising partly from the pleural ridge and partly from the episternum and inserted anterolaterally on coxal base serve as the *promotor-levator of leg* (*90* in Fig. 7A). *Extracoxal flexor of leg* (*91* in Fig. 5) is a muscle that arises from the base of furcal arm and is inserted on an apodeme mesially from the trochanter. A set of *furco-coxal muscles* (*92, 93, 94* in Fig. 5) connect the furca with the hind coxa. The intrinsic muscles of the hind leg comprise four muscles (*95, 96, 97, 98* in Fig. 5B), arising in coxa from four places but inserted in trochanter at two points. Reductor of femur, flexor and extensor of tibia, flexor of claw and flexor of tarsus are the same as in mid

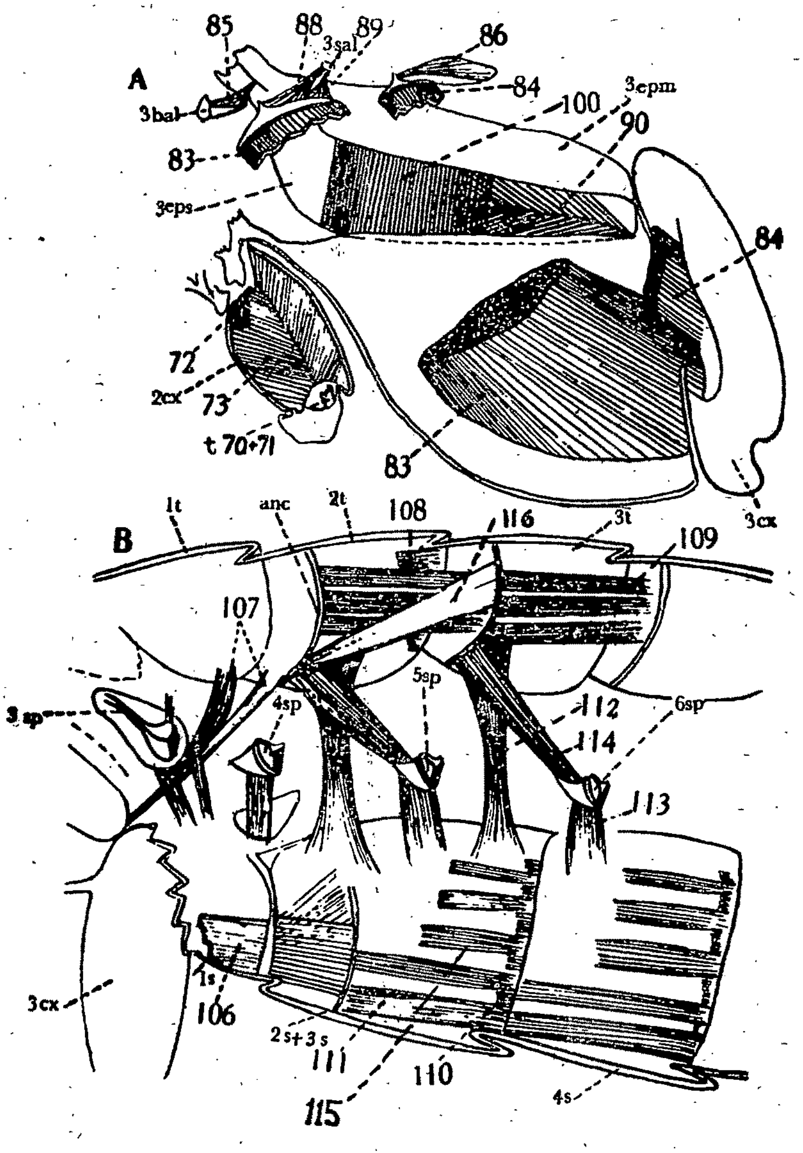

FIG. 7. Musculature of metathorax and abdomen A. Part of musculature of metathorax. (X 17) B. Muscles of the abdomen. (X 17) **72.** sternal promotor of leg ; **73.** coxal extensor of trochanter ; **83, 84.** anterior and posterior extensors respectively of wing ; **85.** relaxator-extensor muscle ; **86.** relaxator of wing ; **88, 89.** flexors of wing ; **90.** promotor-levator of leg ; **100.** expirator of metathorax ; **106.** abdominal conjugant muscle ; **107.** latero-ventral abdominal muscle ; **108.** dorsal internal muscle ; **109.** external dorsal ; **110.** ventral internal ; **111.** ventral external medialis; **112.** tergosternal muscle ; **113.** dilator of the spiracle ; **114.** lateral intersegmental

muscle ; **115.** ventral external laterales ; **116.** paradorsal muscle. *anc.* antecosta ; *3bal.* basalare of metathorax ; *2cx 3cx* coxae of mid and hind legs respectively; *3epm* metepimeron; 3*eps.* metepisternum; *is.* first abdominal sternum; 2*s*+3*s.* fused sternal plates of second and third abdominal sterna; *4s.* fourth abdominal sternum. 3*sal.* subalare metathorax; 3*sp-6sp.* first to fourth abdominal spiracles; *1t, 2t,* 3*t.* first, second and third adominal terga respectively.

legs. When the musculature of coxa of *Mylabris* is compared with *Dytiscus* it is seen that in the latter the muscles are more in number, as each of the extensor consists of an anterior, posterior and an inferior bundle. Similarly the flexor consists of median, lateral, and flexor muscles. This gives increased efficiency to the leg. This is an adaptation for swimming in *Dytiscus.* The legs in *Mylabris* are used only for walking and clinging; therefore such an elabrote musculature is not met with. A *sternopleural muscle* (*99* in Fig. 5) stretches between an apodeme anteriorly from the metasternal apophyses to be inserted on an apodeme on the anterior-most point of pre-episternum. The *expirator of metathorax* (*100* in Fig. 7A) that helps in the respiratory movements extends from the pleural ridge to the anterior margin of pre-episternum. It is composed of a single layer of muscle fibres running parallel to each other, forming a sheath-like structure. Three muscles (*101, 102, 103* in Fig. 5A) pass from the metasternal apophysis to the metathoracic posterior phragmata and are known as *furcodorsal muscles.*

The *extrinsic muscles af the abdomen* (*104,* *105* in Fig. 5A) comprise a pair on each side arising from the posterior phragma of metathorax and inserted on the second apparent abdominal tergite. Another muscle, *abdominal conjugant muscle* (*106* in Figs. 5A, 7B) takes its origin on the posterior phragma and is inserted on the first abdominal sternite.

MUSCLES OF THE ABDOMEN

The principal muscles of a typical segment of abdomen comprise the longitudinal, dorsoventral, and pleural muscles. These muscles serve to fix the abdomen on thorax or telescope the segments or for curving the abdomen, as well as in respiratory movements. Special muscles are inserted in the genital structure.

Muscles of the first abdominal segment.—The *dorsal longitudinal muscles*, which comprise two pairs (*104, 105* in Fig. 5A), originate on the antecosta of the second abdominal tergum and are inserted on the phragma of metathorax. The first pair (*104*) is median while the second (*105*) is outer. Their contraction brings the second abdominal tergum near the metathorax, thereby shortening the abdomen. Bauer (1) has described similar muscles as metaphragma abdominal conjugant muscles and homologizes them with dorsal abdominal muscles. *A lateroventral abdominal muscle* (*107* in Fig. 7B) originate from two places : (*i*) Posterolateral margin of the first abdominal tergum and (*ii*) from anterolateral margin of second abdominal tergum. Both the muscles join together and form a single bundle which is inserted on the outer posterior margin of metepimeron. It runs obliquely and passes below the first abdominal spiracle. Its contraction reduces the pleural membrane by folding it. Ventrally the abdomen is joined to the thorax by a short but thick muscle bundle (*106*) (described in metathoracic muscles). The first abdominal spiracle has a pair of *dilators of the spiracle* (*113*) They originate on the outer margin of the first abdominal sternum. It is inserted on the ventral margin of the peritreme of the first abdominal segment. Its contraction opens the spiracle.

Musculature of the second and third abdominal segments.—The musculature of these two segments is described under one head because they have connate sternum. Their terga are separate. The *dorsal longitudinal muscles* include two groups of fibres in each tergum. Both are intersegmental. One group consists of big *internal dorsal muscles* (*109*). They originate posterior to the antecosta of second abdominal tergum and are inserted anterior to the antecosta of third abdominal tergum. The other group consists of small *external dorsal muscles* (*108*) covered by the internal muscles. They originate from the posterior margin of the second abdominal tergum and are inserted on the anterior margin of the third. In each segment, dorsally, there is a pair of *paradorsal muscles* (*116*). Each muscle is very strong and originates from the anterolateral margin behind the antecosta of the tergum and runs to the inner side to be inserted on the antecosta of succeeding segment. It runs above the internal dorsal longitudinals. *Lateral intersegmental muscles* of second segment (*114*) originate below the paradorsal muscles. They run laterally behind to be inserted dorsally to the spiracle of the succeeding segment. *Tergosternal muscles* (*112*) run between the tergum and sternum of each segment, laterally. Each muscle is inserted on the tergum behind the antecosta and stretches up to the sternum. Thus the connate sternum has two such muscle bundles. This proves the fusion of two sterna. By the contraction of these muscles the abdomen is compressed dorsoventrally. The dilator muscle of the second abdominal spiracle does not originate on the sternum as in the case of third abdominal spiracle but it originates from the laterosternite. The ventral longitudinal muscles consist of the larger *internal longitudinal ventral muscles* (*111*) and the shorter *external ventral longitudinal muscles* (*110*). They are intersegmental in position. The internal muscles have the lateral smaller bundles (*115*) and somewhat bigger median bundles (*111*). The connate sternum has the muscles of both the segments which have fused. The second segment consists of small fibres while the third segment has longer fibres, nearly as big as in the fourth abdominal sternum.

Some of the longitudinal and dorsoventral muscles of eighth and succeeding segments are greatly modified and function as muscles of the male and female genitalia.

Coxo-abdominal conjugant muscles as found in *Dytiscus* are absent in *Mylabris*.

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NOTES ON LIFE-HISTORIES OF SOME COMMON BEETLES*

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This present paper presents notes on life-histories of 14 species of common beetles belonging to seven different families. They were reared in the laboratory in most cases from the egg-stage and their habits and the description of their immature stages are given where necessary.

1. *Hister trigonifrons* Marseul. (Histeridae)

After the first description of the species by Marseul in 1861, based on specimens collected from Ceylon, there seems to be no published record of the species. All stages were collected from Delhi.

Beetles are scavengers and occur under dung. The female lays its eggs singly under dung, either just on the surface of the soil or sometimes two to three inches deep. The freshly laid egg is cylindrical, with both ends broadly rounded, almost transparent and creamy-yellow It measures 3 to 3·5 mm. long and 1.2 to 1.5 mm. broad. As development proceeds, it becomes translucent and acquires a darker colour. Under internal pressure, usually one side becomes slightly convex at the expense of the other, which becomes concave. Hatching takes place 3-4 days after oviposition during September and October.

Grub (*1st stage*).—Head dark brown, about twice as broad as long, dorsal surface smooth but having several longitudinal furrows, anterior margin irregular, somewhat conical in the middle, 2-3 fine hairs on each side; antennae darker, 3-jointed, the basal two joints stout, the apical rudimentary; mandibles very strong, narrow, long and curved, without dentation, ending in a fine point anteriorly. Pronotum slightly larger than the head, narrower anteriorly, amber-

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*Contribution No. 38 from the School of Entomology, St John's College, Agra. The observations recorded here were partly made before Mr. Bose joined the School of Entomology, but written up under my supervision—*M. S. Mani.*

coloured with darker patch behind, a fine median carina with two longitudinal incomplete furrows on either side, the outer curved, the inner straight; meso- & metanota smaller, light smoky with a pale yellow tinge, a darker patch in the middle, sometimes broken at the ends, a row of 9-10 hairs in the centre of the segment extending breadthwise. Abdomen 9-segmented, almost similar in colour to the meso- & metanota, but without central dark patches and having larger number of hairs. Each segment is deeply furrowed dorsally by 3 furrows, the anterior convex, the posterior concave and the central straight, all three converging to a point at either end. The two-jointed siphons at the posterior end of the abdomen dark amber in colour and bear 4-5 long hairs. Length about 13 mm., breadth 2 mm.

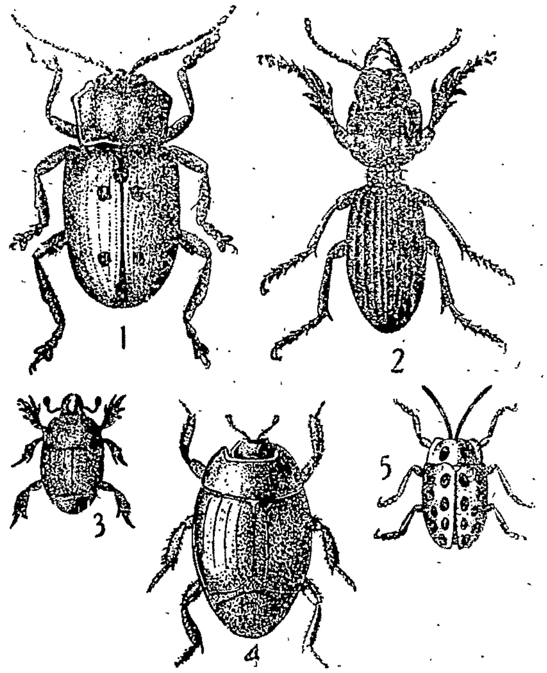
Although like the adults found under dung heaps, the larvae have different feeding habits. Workers of soil termites, chiefly *Termes obesus*, are usually attracted to dung after some days of its deposition and the grubs of this beetle were found to prey on white-ant workers. In breeding cages, living termite workers were supplied to beetle grubs and were readily eaten up. It is thus probable that the grubs of *Hister baconi*, in addition to being scavengers exercise some control on the termite population in soil. Grubs of *Aphodius modestus* occurring in the same environment were also found to be eaten up on several occasions.

The full grown grub prepares a round ball of dung and mud, in which it pupates. The grub stage seems to be very long. Grubs hatched in September and October remained in this stage throughout winter. Hibernation takes place in the grub stage. The grubs which pupate well before winter emerge as adults after 10-12 days. The pupa is ventrally almost flat and circular, slightly narrower posteriorly, pale yellow and measures about 8 mm. long and 5½ mm. broad. The beetle emerges from the mud ball by cutting it at one end.

2. *Hister chinensis* Quens. (Histeridae)

This species is fairly widely distributed in India and China. Its immature stages were collected under dung at Delhi and Dehra Dun. It is similar to but much larger than the grub of

Hister trigonifrons and has also similar habits. Some partially developed grubs collected on 1. x. 38 prepared mud cells for pupation on 10. x. 38 and actually pupated in the mud ball on 13. x. 38. It was noticed that a beetle emerged from pupal case inside the ball on 18 x. 38 but came out of the mud ball on 20. x. 38. Thus, the pupal period is 5-7 days in October.



1. *Podontia quatuordecimpunctata.* 2. *Scarites indus.* 3. *Cypturus aenescens.* 4. *Hister trigonifrons.* 5. *Epistictia viridimaculata.*

3. *Cypturus aenescens* Erichson. (Histeridae)

The immature stages of this species are quite common at Delhi from August to November under cattle dung in fields. Eggs are laid singly either in the dung itself or under it on the soil or even a few inches deep in the soil. Freshly laid egg measures about 2.5 mm. long and 1.5 mm. broad. It is creamy-white, almost transparent and cylindrical, very similar to but smaller than that of *Hister trigonifrons.* Eggs collected from the field during September and October hatched after 3-4 days. Some eggs laid in the laboratory on 18th & 22nd September hatched on 22nd & 26th September, i. e. after 4 days.

Grub (*1st stage*).—Freshly hatched grub measures about 6.5 mm long and 1.5 mm. broad. Head is dark brown, about 1½ times as broad as long. A median vertical line starting from the middle of posterior margin bifurcates into two branches after a little distance, giving it a Y-shaped appearance, two long hairs on each lateral margin, well apart. Antennae also dark brown, 3 jointed, the terminal joint small; mandibles blackish-brown curved and thin, without dentation, tips almost touching in front and enclosing a circular free space. Pronotum about the size of head, brownish along the margins, a large reddish-brown patch in the middle and a small triangular patch medially near the anterior margin. Meso and metanota very narrow, pale yellow, without any peculiarities. Abdomen 9 segmented, segments light yellow, bearing numerous hairs without any furrows, the segments becoming progressively smaller posteriorly. Two-jointed siphons, darker in colour and carrying two long hairs on the tip and another two hairs at the intersegmental line.

The grubs as well as adult beetles are scavengers and feed mainly on cattle dung in different stages of decomposition. Pupa naked in soil and when freshly formed of a creamy colour. During October-November the pupal period is about 8 days.

4. *Oniticellus pallipes* F. (Scarabaeidae)

Of the four species of *Oniticellus* known from the faunal limits of India, *O. cinctus* and *O. pallipes* are the commonest throughout the plains, *O. spinipes* comes next and *O. pallens* is the least common, being known only from N. W. F. Province and Sind.

This species is common at Delhi. Before egg laying the female prepares an oval smooth cavity in a dung ball in which one egg is deposited. These balls are found buried two to three inches under the soil surface. The egg is creamy or pale yellow, broadly rounded at both the ends and measures about 2.5 mm. long and 1.3 mm. broad in the middle. It is usually slightly convex on one side and correspondingly concave along its other side. The grub hatches in one to two days and begins to feed on the dung inside the ball. The first abdominal segments of the grub are very much drawn out and enlarged for the reception of the alimentary canal, which is more than double the length of the body. The body is thus sharply flexed in the middle, the head is comparatively small, without eyes, and with very small antennae. The general colour of the body is whitish but may turn black after the grub has fed for sometime. A large number of individuals were reared to the adult stage during September & October and it was found that the grub stage lasted 10—16 days and the pupal stage 6—9 days. According to Lefroy, larval and pupal stages together occupy 19 days.

The pupa measures about 7 to 7.5 mm. long and 3.7 to 4.2 mm. broad just below the hump. The sharp abdominal flex of the grub is noticed in the pupa too. Thus the head is turned in front almost at right angles to the rest of the body and lies between the first pair of folded legs.

The adult beetle is yellowish-brown with considerable darker spots and at places greenish-metallic tinge. The pronotum is very large, almost as long as the elytra. The beetle measures about 8 mm. long and 4 mm. broad and is a dung feeder.

5. *Aphodius moestus* F. (Aphodiinae)

It is widely distributed in India, Ceylon, Transvaal, East Africa and Madagascar. All the stages were found in dung at Delhi. Ash-coloured oval eggs are laid singly in soil under dung. The incubation period is about 2 days in September. The grubs on hatching feed on dung and when full grown make round black balls in which they pupate. The larval period lasts 9—14 days and the pupal stage is completed in about 5—8 days.

6. *Philonhus cinctulus* Er. (Staphylinidae)

All stages of this species, known to be distributed throughout India and Ceylon, were found in cattle dung at Delhi and the beetles were successfully reared from the egg stage. The egg is oval in shape and dull yellowish in colour. It measures about 2.5 mm. long and 1.2 mm. broad. The peculiar feature of this species is that unlike the Scarabaeid beetles, its grubs thrive in dry dung and are extremely active and run fast. The grub in the last stage measures about 16 mm. long and 2.3 mm. broad. When full grown the grubs pupate naked in dung and the adult beetles emerge therefrom in 7—8 days during September. The adults are also scavengers and feed in dung.

(7) *Philonthus delicatulus* Boh.
(8) *Philonthus aenipennis* Boh.

The grubs of these two species were collected in dung in Delhi in November & December. These continued feeding during winter and pupated in February. Pupal period of *P. aenipennis* Boh. last for 15 days. Like *P. cinctulus* the adults of these two species also feed in dung and are not adversely affected by loss of moisture.

9. *Sphaeridium quinquemaculatum* F. (Hydrophilidae)

In India, this beetle is known to occur at Dehra Dun (U.P.), Belgaum (Bombay), Karachi (Sind), Pusa (Bihar), Jorhat (Assam), etc. Outside India, it is recorded from Ceylon, Formosa, China and Central Africa. Grubs and pupae of this beetle were collected in fair numbers under dung heaps at Delhi in November. From freshly formed pupae the adult beetles emerged in 4—6 days in November. The grubs as well as adults are scavengers.

10. *Scarites indus* Oliv. (Carabidae)

This is one of the commonest Carabid beetle occurring throughout India & Ceylon, but not known from elsewhere. Fletcher in his second hundred notes on Indian insects has figured the pupa and adult beetle.

Grub.—Length about 25 mm., breadth 3.75 mm. General colour of body black. A pale white band along the lateral aspect of all the abdominal segments; dorsally a band of sepia colour. The three-jointed cerci almost transparent and amber-coloured. The femur and tibia dark chocolate and the one-jointed tarsus amber coloured. The body is broad at the base of abdomen and tapers posteriorly.

At Delhi the grubs are abundant under cow dung in November. They are extremely active and when released near dung heap they immediately go under it into the soil.

The adults of this species occur in association with soil termites (*Termes* sp.) frequenting cow dung. In the laboratory the adults remain alive for several weeks by feeding on the termite workers.

11. *Chlaenius rayorus* Bates. (Carabidae)

This predacious species is quite common throughout India. At Delhi, I found a large number of grubs of this beetle predating on caterpillars of *Antigastra catalaunalis* in leaf folds of sesamum and on *Hymania fascialis* larvae defoliating leaves of *Digera arvensis*. The beetle emerges within 3—4 days of pupation. In the laboratory these grubs feed on the caterpillars of *Earias fabia*, *Earias insulana*, *Platyedra gossypiella* and *Chilo zonellus.*

The grub is black excepting the head, which is light chocolate. The mandibles are dark chocolate, very stout and strongly curved. The three pairs of legs are also well developed and allow it to walk swiftly as well as to hold the prey firmly. When full-grown it measures about 13 mm. long and 2 mm. broad. There are several examples of this species in the Forest Institute, Dehra Dun, labelled as predating on caterpillars of *Pyrausta coclesalis* & *Sylepta derogata.*

12. *Apoderus tranquiaricus* F. (Curculionidae)

The adult weevils and their grubs feed on tender leaves of *Shorea robusta* at Dehra Dun. The damage is rather extensive. The weevil rolls up the tender leaves and deposits an egg inside it. The young grub feeds within and pupates. The adult weevil emerges by cutting a hole or crawling out through the fold. The grub has a large dark brown head with a lighter patch in the middle, and numerous hairs. The rest of the body is mixed yellow and brown. The first three abdominal segments are the biggest and conspicuously bulged out. They carry several rows of long hairs running transversely in the middle of each segment.

13. *Podontia quatuordecimpunctata* L. (Chrysomelidae)

Measuring 12-15 mm. long and 6-9 mm. broad, it is one of the largest Halticinae from Indian region. It occurs in U. P., Bengal, Assam, Burma, Andaman Islands and Malaya. It is recorded on *Spondias mangifera* in July and August on *Spandias dulcis* in Federated Malaya States.

In July 1838, the grubs and adults of this species were found severely damaging leaves of *Duabanga sonnertoides* at Dehra Dun (U. P.). The grubs bite holes into the leaves as well as feed along the margin eating away the entire leaf excepting the bigger veins. As a result of this attack several trees were found completely defoliated in a couple of months.

The full grown grub measuring about 20 mm. long and 6 mm. broad, possesses a well developed black head with small but strong mandibles. The pronotum and 3 pairs of legs are also dark brown to black. The meso and metanota and the abdominal segments are brownish-yellow with several irregular darker furrows. There are six minute black dots on each segment, four in a row in front (two on each lateral aspect) and two near the posterior margin. When fully developed the grubs go to the soil surface, collect dry leaves and soil granules into a mass and pupate within.

The pupa is brownish-yellow, markedly convex dorsally. The pronotum bears 6 small hairs along the anterior margin and 2 more on either side along the lower margin. Meso and metanota and the abdominal segments similarly carry a row of 5-6 hairs. There are prominent spiracles on the first five abdominal segments.

14. *Epistictia viridimaculata* Boh. (Chrysomelidae)

This beetle with several of its varieties occurs in the Punjab, U. P., Assam, Nepal, Burma, Siam, Indo-China and Malaya States.

In July 1938, large number of adults and pupae were collected from leaves of the shade tree *Stereospermum suaveolens* at Dehra Dun (U. P.). One hatched egg cluster was also found, an examination of which showed that eggs are laid on the leaf in clusters of about 90 eggs arranged compactly in a single layer. The young grubs skeletonise the leaves. Larger grubs devour entire leaves. When full grown, they fix themselves on the leaf surface and pupate. The last larval moult is usually deposited near the posterior end. Almost all the black spots which are found on the pronotum and elytra of the beetle are also seen in the pupa. General colour of the pupa is white or pale yellow, the abdominal segments being distinctly separated by orange or brick-red intersegmental bands.

EXFOLIATIVE CYTOLOGY OF UTERINE AND CERVICAL CANCERS

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Cancer of the uterus and cervix are exfoliative lesions. The possibility of utilising this natural exfoliative process for the recognition of physiological and pathological changes occurring in the female genital tract and more particularly for the diagnosis of malignant lesions has been discussed in a number of papers in recent years.

Papanicolaou in 1928, (25) by demonstrating exfoliated cancer cells in vaginal smears, gave a stimulus to this method of approach in diagnosis of malignancy. Since then, besides the vaginal smears, fluids from different sources in the body have been studied for the presence of cancer cells by a number of workers. They have used Papanicolaou's original method or its various modifications. The evaluation of the status of cytological diagnosis of cancer by a conference (9) of 6 pathologists and clinicians organised by the American Cancer Society is significant. It was concluded that the 'Value of the cytological method was established in some fields; and that investigations of this method in other fields could be continued. To date accuracy has been achieved in the diagnosis of cancers of the uterus to the extent of 96 to 99·7 per cent (24, 27, 31) in pulmonary cancers to the extent of 82·4 to 96·6 per cent (18) and in prostatic cancers to the extent of 86·5 per cent (30).

Cancer is still a major problem all over the world. The results obtained in its treatment are unsatisfactory. The poor results are due in large measure to the fact that diagnosis of malignancy even today depends to a great extent upon the clinical manifestations which may present themselves only when the disease is far advanced. This is partly due to reluctance of the patients to submit to diagnostic biopsy and partly to the lack of facilities for specialised operative technics *e.g.* bronchoscopy, gastroscopy etc. Under the circumstances, any diagnostic procedure facilitating early diagnosis of malignancy is worthy of serious consideration. This will be still more true of a method which does not require any special operative procedure. The study of exfoliative cytology has provided the pathologist with such a method.

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HISTORICAL REVIEW

Papanicolaou began the study of morphologic and cyclic variations in the cells of the vagina of guinea pigs in 1917 and for the first time in 1923 he suggested the application of the technic to human cancer. The results of these studies were published by him (25, 26) in 1928 and 1933. In 1943 a monograph was published by Papanicolaou and Traut (27) and this together with another publication by Meigs *et al.* (24) few months later giving the report of 220 cases investigated by them, brought the method to the attention of the medical profession.

Meigs *et al.* (24) in 1943 published a report of 200 cases with an error of 2.2 per cent in cervical cancers and 8.3 per cent in endometrial cancers. The false positives were 2.6 percent. These figures correspond closely to 9.3 per cent error in fundus cancers and 1.6 per cent error in cervical cancers reported by Papanicolaou and Traut (27). They reported no false positives. Ayer (1) reported the presence of cancer cells in the vaginal smear in 95 per cent of 40 cases with cancer of the uterus.

Freemont Smith *et al.* (11) Jones, Neusteadter and Mackenzie (19) and Ayer, Bauld and Kearns (4) confirmed Papanicolaou's (26) findings. Gates and Warren (13) reported upon 341 vaginal smears from 233 women and opined that this procedure was promising in a high degree. Ayer and Dakin (5) described the glycerine mailing technic of vaginal smears, which has proved a very practical method for getting specimens from out station. In 1947 he (2, 3) reported the usefulness of the 'spatula cytology technic'. Meigs (21) agreed with Ayer (2,3) that in some cases cervical smears may be of greater value than vaginal smears.

A note-worthy contribution to our knowledge on vaginal cytology has been the publication of 'Hand-book for the diagnosis of Cancer of Uterus by use of vaginal smears' by Gates and Warren (14).

Graham (15) reported the cellular changes in the vaginal cells in post-irradiated cases. She came to the conclusion that first smear diagnosis was more accurate than single biopsy in early cases of cancer cervix. In 1949 Brown (8) after a study of 5314 smears advocated that all women over 30 years age seeking medical advice should be given the benefit of routine vaginal examination. This will help not only in improving the results of routine examination but will help in selection of cases for biopsy

In 1950 Friedman (12) published a paper on 'Flourescent Staining for Cancer Cells.' This method increases the efficiency of screening of the smears, the malignant cells taking a typical flourescent stain. This helps in quick detection of such cells. In the same year Joseph Rich (28) reported his 'Gelfoam Technic'. Its results were not reported by him to be superior to the smear technic but he found gelfoam biopsy superior from the standpoint of recognising the character of the tumor.

Ayer (6) reported the changes in the vaginal cytology after a course of penicillin for cervicitis and leucorhoea. Bonime (7) showed the importance of vaginal smear study in determining ovarian development and activity.

Hecht (16) described a new diagnostic approach to certain gynecological disorders. It entails the picture of hyper-oestrinism as revealed by vaginal smear in its relation to fibromylomas, cystic glandular hyperplasia of uterus and certain ovarian tumors. Cuyler (10) after a four year study of 51,022 smears from 15,217 gynecologic and obstetric patients tried to classify them into various groups showing varied abnormalities. Riley (29) published a report on vaginal smear diagnosis after silver carbonate staining which facilitates the recognition of nuclear aberrations in cancer cells.

In 1952 Hecht (17) showed that vaginal smear was a practical follow-up procedure for patients undergoing radiation therapy.

He also found vaginal smear extremely useful in detecting post-radiation recurrences. Meige and Graham (22) observed that local recurrences in post-irradiated and operated cases of cancer of the cervix were recognised by vaginal smear long before it was grossly detectable. They (22) found that in smear cases the cytological diagnosis antedated a positive biopsy by an average of 14.5 months. A higher over-all cure rate should result if local recurrences are recognised and treated earlier.

Wahi and Jain (31, 32) reported results corresponding to that of Meigs and co-workers (21, 23, 24). In a study of 300 cases they reported 96.3 per cent correct results malignancy with a false positive of 1.7 per cent and false negative of 2 per cent.

MATERIAL AND METHODS

The material for the present study was obtained from the out-patient department and wards of the Gynecology Department S. N. Hospital, Agra; Lady Lyall Hospital, Agra; and the Dufferin Hospital, Meerut. Each case was examined and the relevant history and physical findings noted on special requisition forms. Specimens were taken for biopsy wherever possible.

Preparation of Smears : The exfoliated cells were obtained in several ways. Three different smears were taken : vaginal, cervical and endometrial. The vaginal smear was obtained by aspirating secretion from the posterior fornix with a pipette attached to a rubber bulb. Patients were cautioned not to douche 24 hours prior to examination. The secretion obtained was expressed on a marked glass slide, smeared and immediately immersed in a fixative made up of equal parts of ether and 95 per cent alcohol. Cervical smears were obtained either by aspirating the mucus directly from the cervical os, or by scraping the ecto-endocervical junction with a wooden spatula. The endometrial smear was taken by inserting into the endometrial cavity a special cannula to which a syringe was attached. Gentle suction was applied and the aspirated material was spread on slides and fixed.

Glycerine Mailing Technic : This technic has proved useful in obtaining specimens from outstation. After staying in the ether alcohol fixative for one hour or more, the slides are removed from the solution. Without permitting them to dry, a large drop of glycerine is placed in the centre of the smear. A second clear slide is placed face to face with the smear and the glycerine spreads out to cover the entire area, sealing it off completely. Thus each unit is made of two slides: (1) the slide with the smear (2) a clear slide acting as coverslip. The slides are then placed in a box and mailed. The slides can remain in glycerine mounting for two weeks but better results are obtained if this period does not exceed one week.

Staining of smears :

A. Staining solutions :—

(i) Harris haematoxylin (aqueous alum)

Haematoxylin crystals	1.0 gm.
Absolute alcohol	10 c. c.
Ammonium or potassium alum	20 gms.
Distilled water	200 c. c.
Mercurie oxide	0.5 gm.

Haematoxylin is dissolved in absolute alcohol while ammonium or pottassium alum is dissolved in distilled water. Both solutions are heated and mixed. The mixture is brought to boil as rapidly as possible and mercuric oxide is added. When a rich purple color develops, it is removed from the flame and cooled by plunging the container in cold water.

(ii) Orange G 6.

Orange G (O. 5 per cent in 95 per cent ethyl alcohol)	100 c. c.
Phosphotungstic acid	0·015 gm.

Alcoholic solution of orange G is first prepared. The solution is heated as orange G is less soluble. Addition of phosphotungstic acid to the orange G solution intensifies the color. The solution is not filtered.

(iii) E. A. 36.

Light green (0.5 per cent in 95 per cent ethyl alcohol)	45 c. c.
Bismark brown (0.5 per cent in 95 per cent ethyl alcohol)	10 c. c.
Eosin yellowish (0·5 per cent in 95 per cent ethyl alcohol)	45 c. c.
Phosphotungstic acid	0·2 gm.
Lithium carbonate (Saturated equeous	1 drop.

The 0·5 per cent solutions are first prepared using heat, since the solubility of the stains in 95 per cent alcohol is low. The solutions are filtered separately before mixing. Phosphotungstic acid and lithium carbonate are then added.

B. Staining procedure :

Alcohol 80 per cent	5 dips
Alcohol 70 per cent	5 dips
Alcohol 50 per cent	5 dips
Distilled water	5 dips
Haematoxylin	5 to 10 mins.
Tap water	10 dips
Hydrochloric acid (0·5 per cent)	5 dips (no more)
Tap water (running)	5 mins.
Alcohol 50 per cent	5 dips
Alcohol 70 per cent	5 dips
Alcohol 80 per cent	5 dips
Alcohol 95 per cent	5 dips (drain well)
Orange G 6	45 Seconds
Alcohol 95 per cent	5 dips
Alcohol 95 per cent	5 dips
EA 36	1½ minutes
Alcohol 95 per cent	5 dips
Alcohol 95 per cent	5 dips
Alcohol 95 per cent	5 dips
Absolute alcohol	2 minutes
Absolute alcohol and xylol (equal parts)	2 minutes
Xylol	Smear can be left in xylol 3 to 4 hours.
Canada balsam	Mount in balsam before the smear is dry.

RESULTS

The present report comprises a study of 925 smears in 400 cases.

This group of 400 cases included 183 with positive or suggestive cytology, and 217 with negative cytology (Table I).

Of the 183 cases with positive cytology or cytology suggestive of malignancy, the cytology was not confirmed in 5 cases (Table 2).

Of the 217 cases with negative cytology, the negative cytology was not confirmed by histology in 9 cases (Table 3).

TABLE I. Result on 400 Patients

Tests performed	400
Cases with negative cytology	217
Cases with positive cytology	175
Cases with cytology suggestive of malignancy	8
Confirmed cases (Cytology—Pathology)	124
Squamous carcinoma	116
Adeno carcinoma	2
Miscellaneous	6
*Cases not confirmed by biopsy but cytology positive	51

*The 51 cases listed above were not confirmed histologically because biopsy was not done. The clinical diagnosis in each of these cases was carcinoma or lesion suggestive of carcinoma.

False Positives: Table 2 shows the details of 5 false positive cases.

TABLE 2. False positive cytology : (Cases with cytology positive, pathology negative in 400 patients)

Clinical diagnosis	Smear diagnosis	Pathology
1. Cancer cervix	Adeno carcinoma	Tuberculous cervix
2. Cancer cervix	Epidermoid carcinoma	No malignancy (Twice)
3. Cancer cervix	Malignant cells present	No malignancy (Twice)
4. Cancer corpus	Cells suggestive of adeno carcinoma present	Cystic hyperplasia
5. Early Carcinoma of Cervix	Suspicious malignant cells (Twice)	Chronic cervicitis

False negative : Table 3 shows the details of 9 false negative cases.

TABLE. 3 False negative cytology (Cases with cytology negative pathology positive in 400 patients.

Clinical diagnosis	Smear diagnosis	Pathology
1. Bleeding P. V.	No malignancy	Hydatiform mole (Early malignancy)
2. Cancer cervix	No malignancy	Carcinoma in situ
3. Cancer cervix	No malignancy	Epidermoid carcinoma insufficient for grading

Clinical diagnosis	Smear diagnosis	Pathology
4. Cancer cervix tuberculosis of cervix?	No malignancy	Carcinoma in situ
5. Chorion epithelioma ?	No malignancy (Twice)	Chorio carcinoma
6. Chorion epithelioma	No malignancy	Chorio carcinoma
7. Cancer cervix	No malignancy	Carcinoma in situ
8. Chorion epithelioma ?	No malignancy	Chorio carcinoma
9. Chorion epithelioma	No malignancy	Chorio carcinoma

It will therefore be seen that in 400 cases there were 5 false positives (1·25 per cent) and 9 false negatives (2·25 per cent). Of the false positives we feel that only two should be classified as such. Cases number 1, 2 and 3 showed clinically definite malignancy. The radiologist did not wait for biopsy report to start the treatment. Case No. 1 probably had both cancer and tuberculosis. The false negatives comprised mostly of carcinoma in situ and chorio carcinoma.

REPORT OF CASES

Case 1. A 38 years old Hindu female entered the Lady Lyall Hospital because of pain in the lower abdomen for 3 months and bleeding P. V. off and on for 4 months. She had 10 children, the last one 5 years back. Clinical diagnosis of cancer of cervix was made. Vaginal smear revealed the presence of malignant cells suggestive of adenocarcinoma. Biopsy showed the presence of an adenoacanthoma (Figs. IA, IB).

Case 2. A 50 years old muslim female was admitted with profuse bleeding for 7 days, and severe pain in the lower abdomen and back. She had been bleeding for the last six months. Vaginal examination revealed a bulky and soft uterus. Cervix was nomal, right fornix was slightly full and left was clear. No definite clinical diagnosis was made, though adenocarcinoma was suspected. Vaginal smear was diagnostic of endometrial adenocarcinoma (Fig. 2).

Case 3. A Hindu female aged 30 years was admitted to the hospital with the complaints of severe dysmenorhoea and white discharge P. V. since 1½ years. She had two full term normal deliveries, last child was born 10 years back. On examination a bad erosion of the cervix was seen. Clinically it was diagnosed as chronic cervicities ? Early carcinoma of cervix ? Vaginal smear revealed malignant cells (Fig. 3).

Case 4. A Hindu female aged 30 years was admitted to the hospital with a history of bleeding P. V. off and on since 8 months. She had 4 full term normal deliveries, the last one was born 1½ years back, preceding which she had two abortions of 3 months duration each. Clinically she was diagnosed as placental polyp and a piece of tissue labelled piece of placenta was sent for histological section. Histologically it was diagnosed as chorion epithelioma. Vaginal smear showed isolated malignant cells (Figs. 4 A, 4 B).

Case 5. A 40 years old Hindu female was admitted to the hospital with a history of bleeding P. V. and leucorrhoea since 1½ years. She had 4 childern the last was born 28 years back. Provisional diagnosis was carcinoma of cervix. Vaginal smear revealed cancer cells and biopsy showed the presence of an adenoacanthoma (Figs. 5 A, 5 B).

Case 6. A 60 years old Hindu female was admitted for irregular bleeding P. V. for 7 years. Uterus was hard and bulky on examination. Cancer of Cervix was suspected clinically. Smear did not reveal any malignant cells. Biopsy showed the presence of icthiosis uteri (Fig. 6).

Case 7. A Hindu female aged 38 years was admitted for bleeding P. V. since 2 months with foul discharge for the same duration, clinical diagnosis was cancer of Cervix ? Smear showed scattered malignant cells. Biopsy was a cancer in situ (Figs. 7 A, 7 B).

COMMENTS

The value of exfoliative cytology in the diagnosis of carcinoma lies in the correct interpretation of the smear. We have found nuclear changes as the most important criteria of malignancy. Suspicion should be aroused by the reduced nuclear cytoplasmic ratio together with a nucleus which is larger the usual and has an unusual chromatin arrangement. Definite nuclear changes would comprise of (i) abnormal mitotic figures; these may however be absent and this fact should not go against malignancy (ii) prominent nucleoli and (iii) hyperchromatism or densely stained karyosomes and nuclear membrane. Besides the above nuclear changes the cells show anisocytosis.

In cases of cancers of the cervix, Hecht (17) has described 3 types of malignant cells in squamous carcinoma; (i) the fibre cell, a thin elongated cell with a hyperchromatic elongated nucleus (ii) tadpole cell consisting of a head containing a hyperchromatic nucleus and thin cytoplasmic tail, and (iii) a cell resembling the inner basal type of cell, but with decrease of the nucleo-cytoplasmic ratio. The last is the most differentiated type of cancer cell.

A positive diagnosis can be made with greater assurance if groups of malignant cells are encountered than if only single cells are seen. Diagnosis of malignancy based on single cells must be made strictly on nuclear changes. In interpreting groups of cells, variation in the size and shape of the cells should also be taken into account. Histiocytes, endometrial cells and endocervical cells are often mistaken for undifferentiated malignant cells. However these should not be difficult to identify. It is advisable to adhere strictly to the criteria even though it bears the possibility of missing some better differentiated tumors and reporting a few false negative smears.

The figures of accuracy in the present series are 96 per cent, with false positives 1.25 per cent, and false negatives 2.25 per cent. This is in accord with the findings of Meigs *et al.* (23) and Papanicolaou and Traut (27) (96 to 99.7 per cent). It is important to bear in mind that a negative smear does not rule out cancer, neither should it be considered as a failure of the technic. It only means that the cells are not being exfoliated. Confirmatory biopsy is essential. A negative smear should never outweigh other evidence in favour of malignancy. The question which the surgeons constantly ask is 'whether radical surgery can be undertaken on the basis of smear report alone'. It cannot be answered in the affirmative so long as there is a possibility, even though very remote of a false positive report. We feel that a positive smear should be confirmed by a positive biopsy before radical therapy is undertaken.

Greatest importance of exfoliative cytology lies as a screening test, especially when other methods of detection fail or are not available. In a study conducted by Lombard *et al.* (20) in Boston with a view to evaluate vaginal smears in the diagnosis of symptomless group, 8 positive smears were found and it was concluded that cytological tests may reveal uterine cancer in 1 of 200 to 300 women free from symptoms. In the patients with gynecological symptoms, 133 positive smears were obtained of which 89 were confirmed by biopsy.

The advantage of this method lies in its simplicity. It is a relatively quicker method. Fixation and staining of the smears does not require more than 45 minutes on an average. It is inexpensive and can be repeated as many times as necessary. This is of value in following up suspicious and irradiated cases. It does not require hospitalization and therefore it is particularly adapted to examination of patients in hospital or public health clinics and in private practice. It permits a diagnosis in relatively early stages, in many cases, even before the appearance of clinical symptoms. The really difficult part of this method is the interpretation of smears, which requires special training and experience. These can however be mailed to the specialised laboratories for report. This precaution is essential if the confidence of the clinicians has to be maintained in this diagnostic procedure. It is believed that the technic may help to lower cancer mortality by early diagnosis of malignancy.

SUMMARY

1. A study on 400 cases of suspected carcinoma of uterus and cervix, attending the Gynaecological Out-Patients Department was done. Accurate results were obtained in 96 per cent cases with a false positive of 1.25 per cent false negative of 2.25 per cent.
2. Cancer of the cervix may be diagnosed cytologically before clinical symptoms appear. Cytologic diagnostic criteria for the cancer cells have been defined. Nuclear changes reflect the earliest abnormalities in cellular patterns.
3. Its most distinctive advantages are its simplicity and inexpensiveness, the feasibility of repeated examinations and above all its usefulness in permitting a recognition of early malignant uterine lesions.
4. The cytologic studies of post-irradiation smears serve as a guide in determining prognosis and detecting early recurrence in uterine cancer.

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PLATE VIII.

Fig. 1A—Malignant cells in vaginal smears from a patient with adeno-acanthoma of cervix.
Papanicolaou's staining method. × 485.

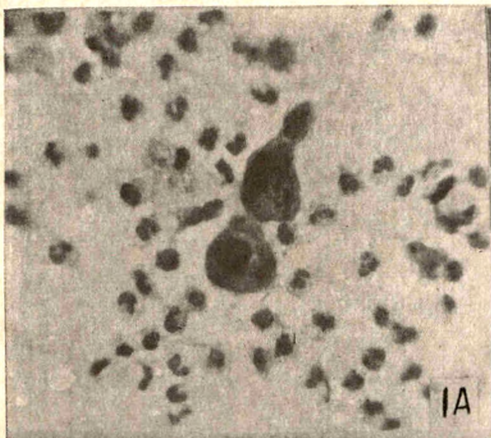
Fig. 1B—Tissue section from the same case as 1 A.
Hemotoxylin and eosin. × 430.

Fig. 2—Adenocarcinoma of endometrium.
Papanicolaou's staining method. × 970.

Fig. 3—Malignant cells in vaginal smear from a case of early cancer of cervix.
Papanicolaou's staining method. × 430.

Fig. 4A—Singly malignant cells in the vaginal smear from a case of chorioepithelioma.
Papanicolaous's staining method. × 430.

Fig. 4B—Biopsy from the same case as 4 A.
Haemotoxylin and eosin. × 100.



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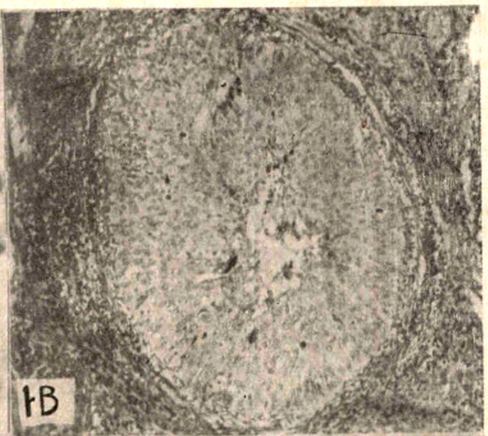

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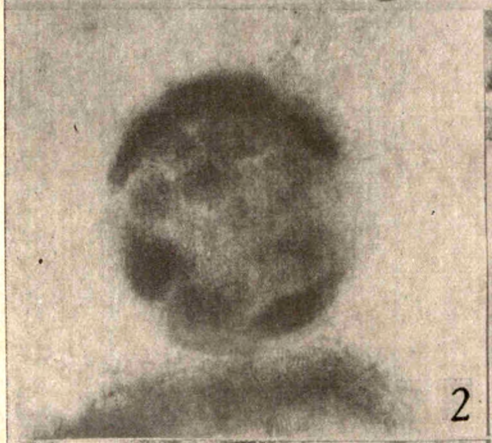

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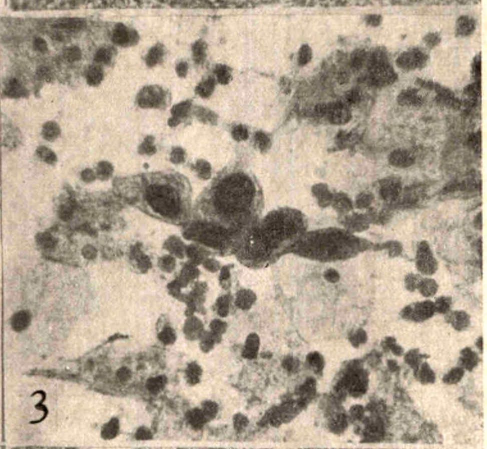

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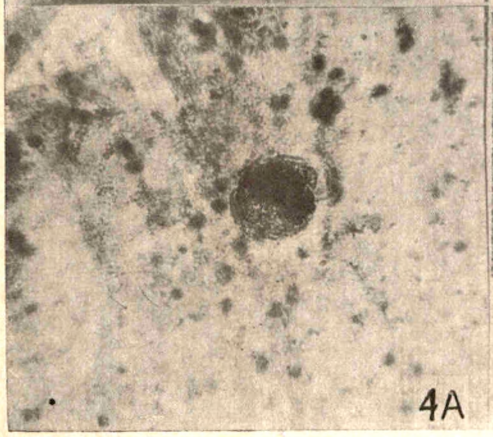

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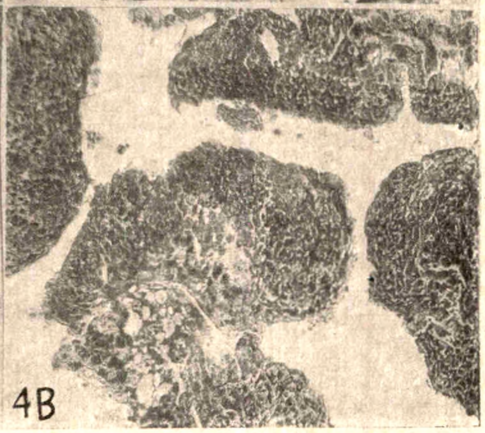

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PLATE IX.

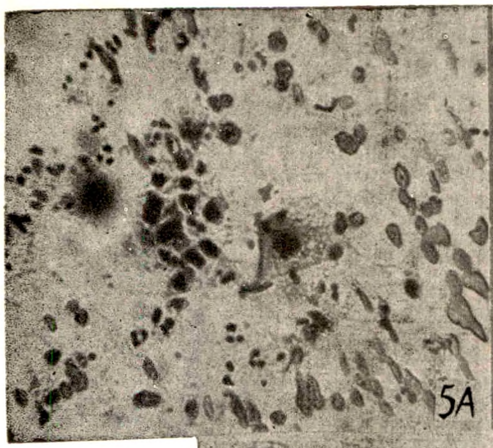
Fig. 5 A—Cancer cells in the vaginal smear from a case of adeno-acanthoma of cervix.
Papanicolaou's staining method. × 430.

Fig. 5 B—Tissue section from the same case as 5 A.
Haematoxylin and eosin. × 100.

Fig. 6 —Microphotograph of the endometrial biopsy showing icthiosis of the epithelium.
Haemotoxylin and eosin. × 430.

Fig. 7 A—Malignant cells in the vaginal smear from a case of cancer in situ of the cervix.
Papanicolaou's staining method. × 430.

Fig. 7 B—Tissue biopsy of the same as 7 A.
Haematoxylin and eosin. × 430.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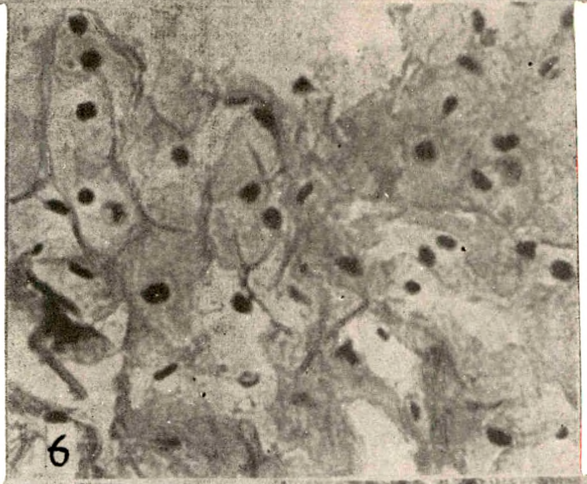
5B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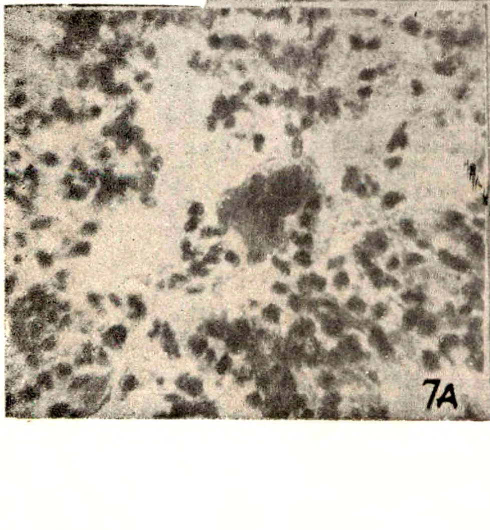
7A

7B

VARIATION AND POST-EMBRYONIC GROWTH IN THE NUMBER OF ANTENNAL SEGMENTS IN THREE SPECIES OF INDIAN SHORT-HORNED GRASSHOPPERS (ORTHOPTERA, ACRIDOIDEA), TOGETHER WITH OBSERVATIONS ON THE NUMBER OF SEGMENTS IN ADULT ACRIDIDAE BASED ON THE COLLECTIONS AT THE FOREST RESEARCH INSTITUTE, DEHRA DUN.

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I. INTRODUCTION

Uvarov (18) gave an account of variation and post-embryonic growth in the number of antennal segments of the family Acrididae. Recently, Roonwal (12 & 13) made a detailed study on variation and post-embryonic growth in the number of antennal segments of *Hieroglyphus nigrorepletus* (Bolivar), and the desert locust, *Schistocerca gregaria* (Forskal), and gave series of generalisations regarding the family Acrididae. I have presented here new data on variation and post-embryonic growth in the number of antennal segments of three species, *viz.*, *Eyprepocnemis roseus* Uvarov, *Aularches punctatus* Drury and *Parahieroglyphus bilineatus* Bolivar. The eggs

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of these species were obtained in 1951 and 1952, both in the fields and by rearings in the laboratory, in and around Dehra Dun. A large number of adults and hoppers of all stages were thus obtained and studied. In addition, the number of antennal segments in the adults of a large number of the species of Acrididae present in the Entomological Collections at the Forest Research Institute, Dehra Dun, were studied.

My sincere thanks are due to Major Dr. M. L. Roonwal, Forest Entomologist, for his stimulating advice and encouragement during the progress of the work. I also thank him for placing the valuable collection of the Forest Research Institute at my disposal for study.

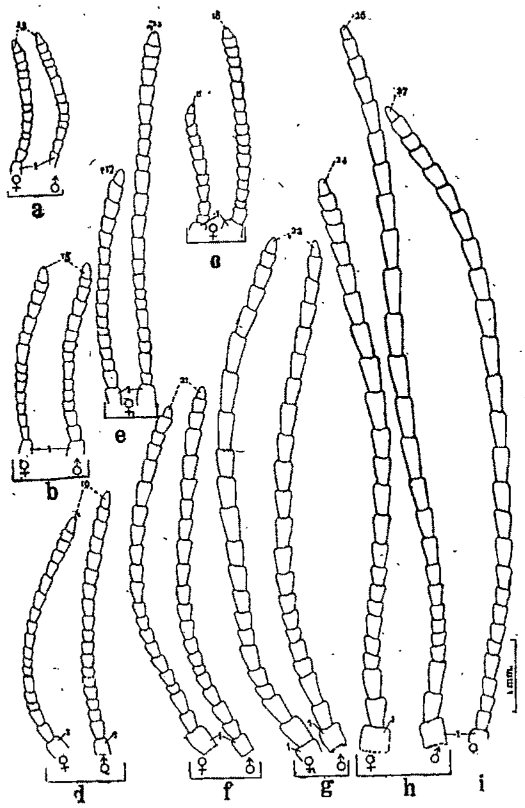
II. VARIATION AND POST-EMRYONIC GROWTH IN THREE SPECIES.

(*a*) **Eyprepocnemis roseus** Uvarov

(Text-fig. 1 & Table 1)

Post-embryonic growth. – The number of antennal segments was carefully counted in all the developmental stages. There are 6 hopper stages and a seventh or adult stage in females; and 5 hopper stages and sixth or adult stage in males. Owing to this extra moulting in females, the adults of that sex have more segments than males. Counts of the right and left antennae were done separately. There is no difference in the right and left antenna in the first two hopper stages, except in a single female of the second stage, which showed a genuine case of asymmetry. From the third to fifth stages, there is no considerable variation in this respect, but the adult or sixth stage of males and the penultimate and the adult (*i. e.*, sixth and seventh respectively) stages of females show marked asymmetry in the same individual and also in the different individuals of the same stage. The number of antennal segments increases from 13 in the first hopper stage (in both sexes) to a maximum of 26 in the male adult (sixth stage) and 29 in the female adult (seventh stage). The number of segments in the different stages are discussed below.

In the first stage the number is 13 and in the second stage 15, except in a single female (Table 1). In the third stage the number varies from 17-23 (mostly around 18-19).



TEXT-FIG. 1—*Eyprepocnemis roseus* Uvarov. Antennae in various stages

(a) First stage antennae of male and female with 13 segments in each. (b) Second stage antennae of male and female with 15 segments in each. (c) Left and right antennae of second stage female showing asymmetry (18 and 11 segment). (d) Third stage antennae of male and female with 19 segments. (e) Third stage (asymmetry) left and right antennae of female with 23 and 17 segments respectively. (f) Fourth stage of male and female with 21 segments in each. (g) Fifth stage antennae of male and female with 22 segments in each. (h) Sixth stage antennae of male (adult) and female with 26 and 24 segments respectively. (i) Seventh stage (adult) antennae of female with 27 segments.

In the fourth stage the number is 21 and rarely 22. In the fifth stage the number is usually 22-24, mostly 22. In the sixth or adult stage in males the number varies from 25-26, mostly 26. In female the sixth or penultimate stage usually has 23-24 (mostly 24) segments, rarely as high as 25 and as low as 22. In the adult female (seventh stage) the number is commonly 26-27, occasionally 29 and rarely as low as 24. The male antennal segments do not show any great abnormal departure from the common condition. In the females, however, this departure is noticeable, and genuine cases of asymmetry as well as much variation are to be found.

Variation.—Following Roonwal (12 & 13), variation in the number of antennal segments can be considered in three respects as below:—

(*a*) Variation in the number of antennal segments in the different hopper stages and in the different individuals of the same stage; (*b*) asymmetrical variation in the right and left antennae of the same individual; and (*c*) some normal and abnormal variations in the number of segments at each moult.

Variation in the post-embryonic growth in the antennal segments has been discussed above. This variation was noticed from the third hopper stage onward. It is evident (Table 1) that the first and second stages have complete symmetry in the number of antennal segments, except in one second stage female which showed a genuine case of asymmetry and had 11 segments in the right and 18 in the left antenna, thus showing the unusually large difference of 7 segments. From the third stage onward, I notice the occurrence of intra-instar variability and asymmetry in the number of right and left antennae in the same individuals and also in different individuals of the same stage. A genuine case of asymmetry was recorded in a third stage female. Besides these asymmetrical cases, the difference in the number of segments in the right and left antennae of the same individual varies approximately from 1-2 segments in males and 1-3 in females from the third hopper stage to the adult. It is quite evident that both variation and asymmetry are more marked in females than in males.

The increase in number of segments is 2 at the first moult; 4-5 at the second moult (2-7 in one case); 3-4 at the third moult and 2-4 at the fourth moult. At the fifth moult, the increase differs in the two sexes, being 2-3 in males and 1-4 in females. Finally, at the sixth moult (only females) it is 1-3 (2-5 in an abnormal case).

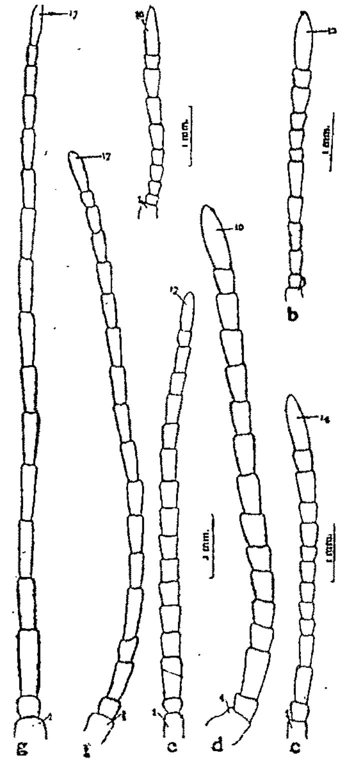
(*b*) **Aularches punctatus** Drury

(Text-fig. 2 & Table 1)

Post-embryonic growth.—In both sexes there are 6 moults and thus 6 hopper stages, the seventh stage being the adult. In each case more than 20 individuals were studied. There is complete bilateral symmetry in all the individuals examined in all stages, though the increase in the number of segments at each moult varies in the different individuals of the same stage (Text-fig. 2). The difference in the number of segments is not correlated with sex. The number of segments increases from 10 in the first stage to a maximum of 18 in the seventh or adult stage (Table 1). There is little variation in the number of segments in the fifth, sixth, and seventh stages, as is discussed below.

In the first stage the number is 10, though in a few individuals the sixth, seventh and eighth segments show some signs of partial division so that there appear to be 13 segments instead of 10. Similarly, in the second stage the number is 12, but in a few hoppers the fifth, sixth and ninth segments (and in two individuals the tenth segment also) show signs of partial division. Thus, the number of segments appears to be 15 or 16 instead of 12. In the third stage the number is 14 and no sign of partial division of any segment is visible. In the older stages (fourth to seventh) little variation in the number of antennal segments is noticeable, and there is no case of asymmetry in any stage. The number of segments in the fourth stage shows slight variation from 15-16 (mostly 16). In the fifth stage the number is 16-17 (mostly 17). In the sixth and seventh stages the number is mostly 17, except in one sixth stage female and in 3 males of the same stage, and in 2 females of the seventh (adult) stage.

The hopper stages can be determined to some extent by the length, width and number of antennal segments, but the sexes cannot be so distinguished. For comparison, it is interesting to note that in the closely allied genus *Poecilocerus pictus* the post-embryonic growth and variation in the number of segments is similar to that in *Aularches punctatus*. *Poecilocerus* has 8 segments in the first stage (9) and 18 in the final or adult stage (13).



TEXT-FIG. 2—*Auiarches punctatus* Durry. Symmetrical antennae in various stages in both sexes

(a) First stage antennae, with 10 segments. (b) Second stage antennae, with 12 segments. (c) Third stage antennae, with 14 segments. (d) Fourth stage antennae, with 16 segments. (e) Fifth stage antennae, with 17 segments. (f) Sixth stage antennae, with 17 segments. (g) Seventh stage (adult) antennae, with 17 segments.

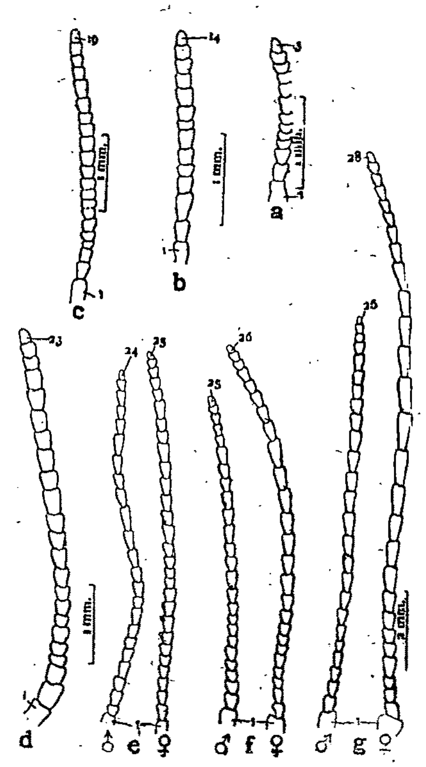
Variation.—There is but little normal variability in the different hopper instars. In the first three stages there is complete bilateral symmetry in the number of segments in the right and left antennae in all the individuals studied. From the fourth to the adult stages all individuals are symmetrical, but the hoppers of the fourth and fifth stages show noticeable variation in the number of segments in the different individuals of the same stage. Further in the sixth and seventh stages there is no marked variation in the number of antennal segments in the individuals of the same stage except in a few hoppers (Table 1). The increase in number of segments is 2 at each of the first two moults, and 1-2 (mostly 2) at the third and fourth moult. No increase occurs in the sixth and seventh stages.

(*c*) **Parahieroglyphus bilineatus** Bolivar

(Text-fig. 3 & Table 1)

Post-embryonic growth.—The increase in the number of segments is from 13 in the first stage of both sexes to a maximum of 27 in adult males and 29 in adult females. In the first two stages the number is 13 and 14 respectively, exactly as in *Hieroglyphus nigrorepletus* (13). The intra-instar variability is first noticed in the third stage in which the number of segments varies from 17-21 (mostly 19, rarely as low as 17 and as high as 21). In the fourth stage the number is usually 22-24 (mostly 23). In the fifth stage in males the number varies from 23-26 (mostly 24) and in females usually 25 (rarely 26). In the sixth stage in males the number varies from 24-26 (mostly 25) and in females from 24-27 (mostly 26). In the seventh or adult stage the number varies from 26-28 (mostly 26) in males, and 26-29 (mostly 28) in females (Table 1 & Text-fig. 3)

Variation.—Variation in the post-embryonic growth in the antennal segments in the two allied species, viz., *Parahieroglyphus bilineatus* and *Hieroglyphus nigrorepletus* (for the latter, see Roonwal, 1952) has been discussed below :—(*a*) Both the species undergo 6 moults and the post-embryonic increase in the number of antennal segments in the various stages, is from 13 in the first stage to a maximum of 29 segments in the seventh (adult). (b) Asymmetry is first evident in the third stage in both species, although the number of asymmetrical cases are more numerous in *H. nigrorepletus* than *P. bilineatus;* in the latter only two



TEXT-FIG. 3. *Parahieroglyphus bilineatus* Bolivar. Antennae in the seven stages.

(a) First stage antennae, with 13 segments. (b) Second stage antennae, with 14 segments. (c) Third stage antennae, with 19 segments. (d) Fourth stage antennae, with 23 segments. (e) Fifth stage antennae of male and female with 24 and 25 segments respectively. (f) Sixth stage antennae of male and female with 25 and 26 segments respectively. (g) Seventh stage (adult) antennae of male and female with 28 and 29 segments respectively.

females showed asymmetry, one in the sixth stage and the other in the seventh (adult) stage. Asymmetry is common in females in both species. However, the difference in the number of segments in the right and left antennae in the individuals of the same stage is more in *Hieroglyphus* than in *Parahieroglyphus.* The increase in the number of segments in *Parahieroglyphus* is 1 at the first moult, 3-5 at the second and about 2-4 at the third moult. From the fourth to the sixth moult the increase at each moult is 1-2 in males and 1-3 in females.

(d) CONCLUSIONS

The following are some general conclusions on the three species studied :—

(i) In the first two stages there is complete bilateral symmetry in all the three species except in one exceptional female of second stage in *Eyprepocnemis roseus* Uvarov.

(ii) Intra-instar variability is first noticeable in the third stage. From then onwards, individuals show asymmetry in the right and left antennae. In *Aularches punctatus*, however, there is no case of asymmetry and there is also much less variation than in the other two species.

(iii) In closely allied species, the post-embryonic increase in the number of antennal segments in various stages is similar, except in genuine cases of asymmetry. Thus, the initial number is 13 in the 3 allied species, *viz.*, *Parahieroglyphus bilineatus*, *Hieroglyphus banian* and *H. nigrorepletus*, increasing up to a maximum of 29 in the adult.

III. ANTENNAL SEGMENTS IN ADULT ACRIDIDAE

(Tables 4-7)

A study was made of the number of segments in some 79 species of adult Acrididae (73 Indian and the remaining foreign), in the collection of the Forest Research Institute, Dehra Dun. In addition, the published data on 8 other species were also studied. These belong to 5 subfamilies as follows :—

(i)	Acridinae	... ...	13 species.
(ii)	Acrydiinae	... ...	8 species.
(iii)	Catantopinae	... ...	46 species.
(iv)	Oedipodinae	... ...	13 species.
(v)	Pyrgomorphinae	... ...	7 species.

Fuller details are given in a table which has been deposited in the Entomological Library at the Forest Research

Institute, Dehra Dun. The following are the more important general conclusions:—

(*a*) Generally, males have fewer segments than females, but in *Atractomorpha* sp. (subfamily Pyrgomorphinae) the males have more segments (17) than females (14-15).

(*b* The range of variation in males is less than in females, but the reverse occurs in three species, *viz.*, *Catantops humilis* Serville, *Gastrimargus transversus* Thunberg and *Atractomorpha* sp. Thus, in 87 species, nearly 16 do not show any variation in the sexes; the females of more than 25 species (Table 7) show greater variation than males; and males of only 3 species referred to above show greater variation than females. In the remaining 43 species, only one sex was available, so that comparisons were not possible.

(*c*) Asymmetry is mostly found in females. However, the American species (Shotwell, 17; and Table 6 here) were bilaterally symmetrical in all stages and also had an equal number of segments in both sexes at each moult. Among the Indian species studied by me, *Aularches punctatus* Drury has complete bilateral symmetry in all stages, and the adults of *A. miliaris* Linn., also have bilateral symmetry.

(*d*) Certain species show slight local variation. Thus all the species of *Oedaleus* from India have 20-24 segments in both sexes, but *O. nigrofasciatus* De Geer from Iraq has 26 antennal segments.

IV. SUMMARY

1. The post-embryonic development in the number of antennal segments in 3 species was studied, with the following results:—(i) *Eyprepocnemis roseus*: The number of segments increases from 13 in the first stage to a maximum of 26 in adult males (sixth stage) and 29 in adult females (seventh stage). (ii) *Aularches punctatus:* The number of segments rises from 10 in the first stage to a maximum of 18 in the seventh stage or adult. (iii) *Parahieroglyphus bilineatus*: As in species of *Hierog-*

lyphus, the number of segments increases from 13 in the first stage to a maximum of 29 in the adult.

2. The intra-instar and intra-individual variation in the antennal segments are clearly seen in *Eyprepocnemis roseus* and *Parahieroglyphus bilineatus*. In *Aularches punctatus* there is complete bilateral symmetry in all individuals of different stages.

3. The range of variation in post-embryonic growth in the antennal segments is mostly noticed after the third stage, and is more marked in females than in males.

4. A study of the number and variation of antennal segments in the adults of 87 species of Acrididae was made. Some general conclusions from this study are given.

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TABLE 2. *Eyprepocnemis roseus* Uvarov —Data on bilateral asymmetry (difference between the right and left antenna of the same individual) in the number of antennal segments. (From data in Table 1, subpara 1.)

Abbreviation.—T. Total

Stage	Total Number examined	Number of individuals showing symmetry (and % of total)	Number of individuals showing asymmetry (and % of total)	Difference in the number of antennal segments in asymmetrical individuals	
				Range	Frequency distribution of differences
I	M 21 F 21	All (100%)	Nil	...	
	T. 42				
II	M 20 F 21	All (100%) 20 (95·2%)	Nil 1 (4·8%)	... 1—7	 7
	T. 41	40 (97·5%)	1 (2·5%)	1—7	7 (1)
III	M 13 F 13	10 (76·9%) 10 (76·9%)	3 (23·1%) 3 (23·1%)	1 1—6	1, 1, 1 6, 1, 1
	T. 26	20 (76·9%)	6 (23·1%)	1—6	1 (5), 6 (1)
IV	M 13 F 13	11 (84·6%) 12 (92·3%)	2 (15·4%) 1 (7·7%)	1 1	1, 1 1
	T. 26	23 (88·4%)	3 (11·6%)		1 (3)
V	M 13 F 13	9 (69·2%) 10 (76·9%)	4 (30·8%) 3 (23·1%)	1—2 1—3	1, 2, 2, 1, 3, 1, 1
	T. 26	19 (73·7%)	7 (26·3%)	1—3	1 (4), 2 (2), 3 (1)
VI	M 16 F 16	14 (87·5%) 10 (62·5%)	2 (12·5%) 6 (37·5%)	1 1—2	1, 1 1, 1, 2, 1, 1, 2
	T. 32	24 (75·0%)	8 (25·0%)	1—2	1 (6), 2 (2)
VII	F 20	15 (75·0%)	5 (25·0%)	1—3	2, 2, 2, 1, 3,

Table 3. *Parahieroglyphus bilineatus* Bolivar. Data on bilateral asymmetry (difference between the right and left antenna of the same individual) in the number of antennal segments. (From data in Table 1, subpara—3.)

Abbreviation.—T. Total

Stage	Total Number examined	Number of individuals showing symmetry (and % of total)	Number of indiviuals showing asymmetry (and % of total)	Difference in the number of antennal segments in asymmetrical individuals.	
				Range	Frequency distribution of difference
I	M 14 F 14	All (100 %)	Nil	...	...
	T. 28				
II	M 10 F 12	All (100 %)	Nil	....	...
	T. 22				
III	M 12 F 12	7 (58·3 %) 8 (66.7 %)	5 41·7 %) 4 33·3 %)	1—2 1—2	1,1,2,1,1 2,1,2,1
	T. 24	15 (62.5 %)	9 (37·5 %)	1—2	1 (6), 2 (3)
IV	M 7 F 9	5 71·4 %) 6 66·7 %)	2 (28·6 %) 3 (33·3 %)	1—2 1	1,2 1,1,1
	T. 16	11 (68·75 %)	5 (31·5 %)	1—2	1 (4), 2 (1)
V	M 7 F 8	5 (71·4 %) 5 (62·5 %)	2 (28·6 %) 3 (37·5 %)	1 1—2	1,1 2,1,1
	T. 15	10 (66·7 %)	5 (33·3 %)	1—2	1 (4), 2 (1)
VI	M 6 F 8	5 (83·3 %) 4 (50·0 %)	1 (16·7 %) 4 (50·0 %)	1 1—3	1 1,3,2,1,
	T. 14	9 (64·3 %)	5 (35·7 %)	1—3	1(3),2(1),3(1)
VII	M 19 F 19	14 (73·3 %) 13 (68·4 %)	5 (26·3 %) 6 (31·6 %)	1—2 1—3	1,1,1,2,1 1,1,3,2,1.1
	T. 38	27 (71·05 %)	11 (28·95%)	1—3	1(8),2(2),3(1)

Table 4.—Number of antennal segments in each stage of normal postembryonic development in some species, where number of segments in the first stage begin with same or nearly the same number and show resemblance in the growth in the final stage (from data in Table 1; & from Roonwal, 1952 *b.*)

Abbreviations,—Ad,, adult; L, left antenna; R, right antenna,

Species (Number of abnormal moults are given in square brackets)	Morphological stage (in Roman numerals) and the number of antennal segments								Source
	I	II	III	IV	V	VI	VII	VIII	
Parahieroglyphus bilineatus Bolivar	13	14	17-21 (mostly 19)	Usually 22-24 (mostly 23)	Vary from 23-26 mostly 24 in male, 25 in female	Vary from 24-26 (mostly 25) in male, and in female 24-27 (mostly 26)	In male 26-28, mostly 26; and in female 26-29, mostly 28	...	Katiyar (Present account)
Hieroglyphus nigrorepletus Bolivar	13	14	18-20 rarely 16-17	Usually 21-23 mostly 21 rarely as low as 16	Usually 23-25 (mostly 23), rarely as low as 20	Usually 26-27, rarely as low as 14-19 and as high as 29	Usually 27-28, rarely as low as 20-22, and, as high as 29 (ad.)	...	Roonwal (1952*b*)
Hieroglyphus banian Fabricius [6] males [7] females	13 13	16 16	19-20 19-20	21-22 21-22	24-25 24-25	25-26 25-26	29 (Ad.) 27-29	29 Ad.	Colemann & Kuhni Kannan (1911) [Figures for females are probable and roonwal 1925b for adults]
Eyprepocnemii roseus Uvarov [5] males [6] females	13	15 a single female, R11, L18	18-19 in a single case R, 17; L, 23	Mostly 21	Usually 22-24, mostly 22 and rarely as high as 24	Male 26, rarely 25 Female usually 22-25 mostly 24	Female only, 26-28 Rarely as high as 29 and as low as 24	...	Katiyar (Present account)
Aularches punctatus Drury	10	12	14-15 rarely 15	15-16 (mostly 16)	16-17	16-17 (mostly 17)	16-18 (mostly 17)	...	Katiyar (Present account)
Poecilocerus pictus Fabricius	8	8 (?) -9	10-11	12-14	15	15-16	18 (Ad.)	...	Pruthi & Nigam (1939) forhoppers; Roonwal-1952*b*, for adults (20, 20)

Table 5.—Number of antennal segments added at each moult in 3 species of Acrididae.

Species (Number of moults indicated in the square brackets)	Number of antennal segments added at each moult between consecutive instars I—VII					
	1st moult (I & II)	2nd moult (II & III)	3rd moult (III & IV)	4th moult (IV & V)	5th moult (V & VI)	6th moult (VI & VII)
Eyprepocnemis roseus Uvarov [male 5, female 6]	2	4—5, 2—7 in one case of asymmetry	3—4	2—4	2—3 in male 1—4 in female	Only in female 1-3, sometimes 2-5 in typical asymmetry.
Aularches punctatus Drury [male & female 6]	2	2	1—2, mostly 2	1—2, mostly 2	1, much increase in length and width in the segments	Mostly segments increase in length, rarely 1
Parahieroglyphus bilineatus Bolivar [male & female 6]	1	3—5	Approximately 2—4	1-2 in male 1-3 in female	1—2 in male 1—3 in female	1—2 in male and 1-3 in female

TABLE 6. Number of antennal segments in adults Acrididae in the collection of the Forest Research Institute, Dehra Dun, with some other published records.

	Species (No. of specimens examined is given in brackets).	Localities	No. of antennal segments in adults		Remarks
			Male	Female	
		Subfamily 1. Acridinae (or Truxalinae).			
1.	**Acrida exalta** Walker (6)	(*i*) Madras : Nilambur (*ii*) U. P. : Dehra Dun, Almora; Thano.	17-19	14-19	One genuine case of asymmetry
2.	**Acrida gigantea** Herbst (4)	(*i*) Bihar : Pusa. (*ii*) U. P. : Dehra Dun, Kansrao, Gonda.	?	18-19	
3.	**Acrida turrita** Linnaeus (5)	(*i*) Bihar : Pusa. (*ii*) U. P : Dehra Dun	18-19	19	
4.	**Acridella nasuta** Linnaeus (1)	U. P. : Dehra Dun.	?	19	
5.	**Aeolopus affinis** Bolivar (1)	U. P. : Dehra Dun	?	18	
6.	**Aeolopus tamulus** Fabricius (37)	(*i*) Bengal : Dacca. (*ii*) Madras : Nilambur	22	22	
7.	**Ceracris deflorata** Brunner (37)	U. P. : Dehra Dun, New Forest, Rishikesh; also?	22-26	24-26	More variation in males than in females
8.	**Keya capicola** Uvarov	South Africa	18	18	Uvarov (1941)
9.	**Phlaeoba panteli** Bolivar (1)	U. P. : Dehra Dun	?	18	
10.	**Phlaeoba ramkrishnai** Bolivar (2)	Madras : Nilambur, Nedungayam	?	18	
11.	**Phlaeoba** sp. (2)	?	?	19-20	
12.	**Pnorisa squalus** Stal	South Africa	?	23	Short antennae
13.	**Pnorisa Curinata** Uvarov	South Africa	?	23	Larger antennae than P. squalus. Both by Uvarov (1941)
		Subfamily 2. Acrydiinae (or Tetriginae)			
14.	**Criotettix grandis** Hancock (4)	Assam : Cachar, Haflong	14	14	
15.	**Eugavialidium indica** Hancock (13)	Assam : Naga hills, (4,000 ft.)	?	13-15	
16.	**Euparatettix personatus** Bolivar (4)	(*i*) Bengal : Tipperah (*ii*) Madras : Nilambur	?	13-14	
17.	**Gavialidium sp.** (1)	Assam : Manipur, Shugnu (3,000 ft.)	?	14	
18.	**Hedotettix gracilis** De Haan (1)	Madras : Nilambur, Nedungayam	?	14	
19.	**Scelimena harpago** Serville (4)	Madhya Bharat : Rewah, Umaria, Jaithari range	?	24	
20.	**Sjoestedtia darjeelingensis** Bolivar (2)	U. P. : Dehra Dun	?	24	
21.	**Thorodonta sp.** (1)	Assam : Manipur, Shugnu (3,000 ft.)	?	15	

	Species (No. of specimens examined is given in brackets).	Localities.	No. of antennal segments in adults		Remarks.
			Male	Female	
		Subfamily 3. Catantopinae			
22.	**Aucacris eumera** Hebard (1)	American sp.	17-18	?	Hebard (1929).
23.	**Catantops humilis** Serville (21)	(*i*) Madras : Nilambur (*ii*) U. P. : Dehra Dun, New Forest; Kheri, also from?	21-25	23-25	More variation in males & asymmetry in females.
24.	**Catantops innotabile** Walker (9)	(*i*) Madras : Nilambur (*ii*) U. P. : Dehra Dun.	23	23-26	More variation and asymmetry in females.
25.	**Catantops karnyi** Kirby (2)	(*i*) Mysore : Coorg, N. Coorg, Fraserpet. (*ii*) U. P. : Dehra Dun	24	24	
26.	**Catantops pinguis** Stal (6)	(*i*) Madras : Nilambur (*ii*) U P. : Almora, kali valley (3,000 ft.)	24	23-25	
27.	**Catantops pulchellus** Walker (1)	Madras : Madura	25	?	
28.	**Catantops splendens** Thunberg (2)	U. P. : Dehra Dun	?	27	
29.	**Chondracris rosea** De Geer (3)	U. P. : Dehra Dun, Thano	29	29	Considerably large antennae in both sexes.
30.	**Choroedochus illustris** Thunberg (4)	(*i*) Bihar : Pusa (*ii*) Punjab : Montgomery (*iii*) U. P. : Dehra Dun.	?	27-28	
31.	**Choroedochus capensis** Thunberg (23)	U. P. : Dehra Dun, New Forest, Rishikesh.	25-27	26-29	Males usually have fewer segments than females.
32.	**Choroedochus robusta** Serville (3)	Bengal : Kalimpong, Samising (3,000 ft.)	?	28-29	
33.	**Coptacra faedata** Serville (1)	Bihar : Pusa	?	24	
34.	**Coptacra punctaria** Walker (1)	Madras : Nilambur	?	21	
35.	**Cyrtacanthacris tatarica** Linnaeus (2)	Madras : Nilambur; Chatambarai	?	27	
36.	**Epistaurus sinetyi** Bolivar (1)	Madras : Nilambur	20	?	
37.	**Ecoptacra** sp. (1)	Madras : Nilambur	?	24	
38.	**Ecoptacra saturata** Walker (2)	Madras : Nilambur	24	24	
39.	**Eyprepocnemis alacris** Serville (5)	Madras : Nilambur	?	25-27	
40.	**Eyprepocnemis roseus** Uvarov (52)	U. P. : Dehra Dun, New Forest, Raipur; Rishikesh.	22-25	24-29	Present account.
41.	**Eyprepocnemis shirakii** Bolivar (2)	Madras : Nilambur	26	?	
42.	**Euthymia kirbyi** Finot	Madras : N. Salem, Jawalagiri	?	25	
43.	**Euthymia** sp. (1)	Madhya Pradesh : Balaghat, Baihar	?	25-26	
44.	**Gesonia punctifrons** Stal (3)	Bengal : Calcutta	22	23	

	Species. (No. of specimens examined is given in brackets).	Localities.	No. of antennal segments in adults		Remarks.
			Male	Female	
45.	**Hieroglyphus banian** Fabricius (36)	(*i*) Bihar : Pusa (*ii*) U. P. : Dehra Dun New Forest, Raipur, Rishikesh (Barkot-range)	26-29	27-29	
46.	**Hieroglyphus nigrorepletus** Bolivar (Also see Roonwal 1952)	(*i*) Ceylon : (*ii*) Rajasthan : Ajmer (*iii*) U. P. : Banaras	29 25-29 28		Micropterous (green) Micropterous (fuscous or fawn) Micropterous (fawn).
47.	**Hieroglyphus** sp. (5)	U. P. : Rishikesh, Barkot-range	26	28	
48.	**Parahieroglyphus bilineatus** Bolivar (48)	U. P. : Dehra Dun, New Forest, Rishiksh (Barkot range).	24-27	26-29	
49.	**Melanoplus femur-rubrum** De Geer (1)	N. America : U. S. A., La. Fayette (Indiana)	? 24*Shot wel1951.	26	
50.	**Melanoplus bivittatus** Sqy	N. America: U. S. A., N. W. Iowa,	24	24	Shotwell (1941)
51.	**Melanoplus differentialis** Thos	N. American : U. S. A. Iowa, Nebraska, Kansas	26	26	Shotwell (1941)
52.	**Melanoplus gladstoni.** Scudder	N. America : U. S. A.	23	23	Shotwell (1941)
53.	**Melanoplus packardi.** Scudder	N. America : U. S. A.	24	24	Shotwell (1941)
54.	**Phoetaliotes nebrascensis** Thos	N. America : U. S. A.	23	23	Shotwell (1941)
55.	**Camnula pellucida** Scudder	N. America : U. S. A.	23	28	Shotwell (1941)
56.	**Dissosteira carolina** Linnaeus	N. America : U. S. A.	24	24Shot well (1951)	
57.	**Oxya apta** Walker (1)	U. P. : Dehra Dun	?	26	
58.	**Oxya velox** Fabricius (2)	(i) Madras : Nilambur, Nedungayam (ii) U. P. Dehra Dun, Gurukul Kangri (Hardwar)	25	25-26	
59.	**Pachyacris vinosa** Walker (10)	(i) Assam : Manipur, 2678 ft. (ii) Madras : Nilambur, Nedungayam (iii) U. P. : Dehra Dun, Kalsi, New Forest.	27-29	23-29	More variation in females than in males.

	Species. (No. of specimens examined is given in bracket.s)	Localities.	No. of antennal segments in adults		Remarks.
			Male	Female	
60.	**Patanga Succinata** Linnaeus (1)	U. P, Dehra Dun,	26	?	
61.	**Patanga succinata Japonica** Bolivar (1)	U, P, Nainital	?	27	
62.	**Schistocerca gregaria** Forskal (15) (see Roonwal, 1951)	(i) Rajasthan : Bikaner, Kakko, Ajmer,	26 26	26 26	Phase solitaria 5 eye-striped.
		(ii) U. P.; Dehra Dun.	26-27	24-26	Phase gregaria.
63.	**Spathosternum prasiniferum** Walker (7)	(i) Madras : N. Salem, Aiyur, Nilambur	21-22	24	
		(ii) Madhya Bharat, Rewah, Amarkantak (3,000 ft.)			
		(iii) U. P. Dehra Dun,			
64.	**Teratodes monticollis** Gray (3)	(i) Madras : N, Salem, Jawalagiri	26-28	?	Specimens from S. India tend to show a lower No. of segments.
		(ii) U. P. Dehra Dun,			
65.	**Thisoicetrus pulcher** Bolivar (3)	(i) Punjab: Montgomery.	26	27-28	
		(ii) U. P. Dehra Dun,			
66.	**Tristria pulvinata** Uvarov	Madras : Nilambur, Nedungayam	23	?	
67.	**Tylotropidius varicornis** Walker (5)	Madhya Pradesh : Raipur, Birgari, Pachmarhi, Hoshangabad (3,500 ft.)	22-23	27	4 males, 1 female
		Subfamily 4. Oedipodinae.			
68.	**Acrotylus** Fieber (7)	U. P, Allahabad, Dehra Dun.	2	23-26	
69.	**Aiolopus savignyi** Krauss (6)	S. Africa : Sudan : Wad Medani	23-24	20-24* Much variation in females	
70.	**Gastrimargus transversus** Thunberg (27)	(i) Bihar : Pusa (ii) Madhya Bharat : Rewah, Amarkantak (3,500) (iii) Madhya Pradesh : Hosangabad. Pachmari (3,500) (iv) Madras : Nilambur (v) U. P. Almora, Dhauliganga; (9520 ft.) Dehra Dun, Chakrata, Kalsi, Mussoorie, Rishikesh, Kumaon, Nainital.	22-26	25-27	More variation in males than females in all localities.

	Species. (No. of specimens examined is given in brackets).	Localities.	No. of antennal segments in adults		Remarks.
			Male	Female	
71.	**Heteropternis respondens** Walker (5)	(i) Madras: Nilambur (ii) U. P. : Dehra Dun.	24	25-26	
72.	**Oedaleus abruptus** Thunberg (16)	(i) Madhya Pradesh: Raipur, Birguri (ii) Madras: N. Salem, Aiyur (iii) U. P.: Dehra Dun, Chakrata, Kalsi; Garhwal, Akeshwar; Gonda; Kumaon.	20-25	23-25	
73.	**Oedaleus nigrofasciatus** De Greer (1)	Extra Indian: Ireq: Amara	26	26	Highest number within genus **Oedaleus**
74.	**Oedaleus senegalensis** Krauss (1)	Madras: N. Salem, Udupurani	24	?	
75	**Pusa rugulosa** Uvarov (1)	U. P.: Kalagarh: Ratwadhab	?	20	
76.	**Sphingonotus indicus** Saussure (2)	U. P.: Dehra Dun	?	23-25	
77.	**Sphingonotus longipennis** Saussure (4)	U. P.: Dehra Dun.	25	26	
78.	**Sphingonotus mecheriae** Voss (1)	Extra Indian: Asia: Iraq: Amara	18-25	??	
79.	**Trilophidia annulata** Thunberg (4)	(i) Madras: Nilambur (ii) U. P.: Dehra Dun.	20-21	21	
80.	**Trilophidia** sp. (1)	Madras: Nilambur	?	21	
		Subfamily 5. Pyrgomerphinae.			
81.	**Atractomorpha** sp. (5)	Madras: Nilambur			
82.	**Aularches miliaris** Linnaeus (2)	Madras: Nilambur, Nedungayam	17 17	14-15 17	Males have higher more number of segments than females. Bilateral symmetry
83.	**Aularches punctatus** Drury (49)	U. P.: Dehra Dun; Dehra Dun, Kamili garden, Jhajra, New Forest.	17	17	Bilateral symmetry in all the individuals examined.
84.	**Chlorizeine unicolor** Brunner (1)	Burma: Pyinmanas, Yanaugymyin reserve	?	19	
85.	**Chrotogonus** sp. (2)	(i) Madras: N. Salem, Aiyur (ii) U. P: Dehra Dun.	?	19	
86.	**Orthacris** sp. (3)	Madras : N. salem, Aiyur	?	19	
87.	**Poecilocerus pictus** Fabricius (11)	(i) Bengal: Shrupur (ii) Rajasthan: Ajmer state, Raoli (2100 ft.) (iii) U. P.: Dehra Dun, Raipur; Etawah; Kalpi.	17-18	17-18	Also see 2 female. 2 male Roonwal (1952).

Table 7.—Maximum difference in the number of segments in the right and left antennae of the same individuals in the 2 sexes in some adult Acrididae. (From Table 6).

Species.	Maximum difference between right and left antennae		Difference. (The sex in which excess number occurs is indicated in brackets).
	Male	Female	
Sub-family 1—Acridinae (or Truxalinae).			
1. **Acida exalta**Walker	1	5	4 (Female)
2. **Acida gigantea** Herbst	—	1	1 (Female)
3. **Acrida turrita** Linnaeus	1	1	0
4. **Ceracris deflorata** Brunner	2	2	0
5. **Phlaeoba** sp.	—	1	1 (Female)
Sub-family 2—Acrydiinae (or Tetriginae)			
6. **Eugaviaiidium india** Hancock	—	1	1 (Female)
7. **Euparatettix personatus** Bolivar	—	1	1 (Female)
8. **Scelimena harpago** Serville	—	1	1 (Female)
9. **Sjoestedtia darjeelingensis** Bolivar	—	1	1 (Female)
Sub-family 3—Catantopinae.			
10. **Catantops humilis** Serville	4	2	2 (Male)
11. **Catantops innotabile** Walker	0	1	1 (Female)
12. **Catantops pinguis** Stoal	0	1	1 (Female)
13. **Choroedochus capensis** Thunberg	1	3	2 (Female)
14. **Choroedochus robusta** Serville	—	1	1 (Female)
15. **Eyprepocnemis alacris** Serville	—	1	1 (Female)
16. **Eyprepocnemis roseus** Uvarov	2	3	1 (Female)
17. **Euthymia** sp.	—	1	1 (Female)
18. **Hieroglyphus banian** Fabricius	1	2	1 (Female)
19. **Hieroglyphus nigrorepletus** Bolivar	1	3	2 (Female)
20. **Parahieroglypnus bilineatus** Bolivar	2	3	1 (Female)
21. **Oxya velox** Fabricius	0	1	1 (Female)
22. **Pachyacris vinosa** Walker	2	5	1 (Female)
23. **Schistocerca gregeria** Forskoal	0	2	2 (Female)
24. **Spathosternum prasinifeum** Walker	1	1	0
25. **Thisoicetrus pulcher** Bolivar	1	1	0
Sub-family 4—Oedipodinae			
26. **Acrotylus Fieber**	1	3	2 (Female)
27. **Gastrimargus transversus**Thunberg	2	1	1 (Male)
28. **Oedaleus abrupttus** Thunberg	1	1	0
29. **Trilophidia annulata** Thunberg	1	1	0
Sub-family 5—Pyrgomorphinae			
30. **Atractomorpha** sp.	3	1	2 (Male)

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